Minerals Yearbook

1978-79

Volume I

METALS AND MINERALS

U.S. DEPARTMENT OF THE INTERIOR

MARCH 3, 1849

Prepared by staff of the

BUREAU OF MINES

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UNITED STATES DEPARTMENT OF THE INTERIOR • Cecil D. Andrus, Secretary

BUREAU OF MINES • Lindsay D. Norman, Director

As the Nation's principal conservation agency, the Department of the Interior has basic responsibilities to protect and conserve our land and water, energy and minerals, fish and wildlife, and park and recreation areas, and for the wise use of all those resources. The Department also has a major responsibility for American Indian reservation communities and for the people who live in Island Territories under U.S. administration.

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Foreword

The Federal Government, through the Minerals Yearbook and its predecessor volumes, has reported annually on mineral industry activities for 98 years. In the interest of expediting the release of minerals data, this edition of the Yearbook covers both 1978 and 1979. It discusses the performance of the worldwide mineral industry during 1978 and 1979 and provides background information to assist in interpreting developments during the years being reviewed. Content of the individual volumes follows:

Volume I, Metals and Minerals, contains chapters on virtually all metallic and nonmetallic mineral commodities important to the U.S. economy. In addition, it includes a chapter on mining and quarrying trends.

Volume II, Area Reports: Domestic, contains chapters on the mineral industry of each of the 50 States, the U.S. island possessions in the Pacific Ocean and the Caribbean Sea, and the Commonwealth of Puerto Rico. This volume also has a statistical summary.

Volume III, Area Reports: International, contains the latest available mineral data on more than 130 foreign countries and discusses the importance of minerals to the economies of these nations. Separate chapters review the international minerals industry in general and its relationship to the world economy and ocean minerals.

The Bureau of Mines continually strives to improve the value of its publications to its users. Therefore, the constructive comments and suggestions of readers of the Yearbook will be welcomed.

Lindsay D. Norman, *Director*

UNITED STATES DEPARTMENT OF THE INTERIOR • Cecil D. Andrus, Secretary

BUREAU OF MINES • [illegible]

Foreword

The Federal Government, through the Minerals Yearbook and its [illegible]

[illegible]

Volume II, Area Reports: Domestic, [illegible]

Volume III, Area Reports: International, [illegible]

The Bureau of Mines [illegible]

[illegible]

Acknowledgments

Volume I, Metals and Minerals, of the Minerals Yearbook presents data on more than 90 nonfuel mineral commodities that were obtained as a result of the mineral information gathering activities of the Bureau of Mines.

The collection, compilation, and analysis of data on the domestic minerals industries were performed by the staffs of the Sections of Ferrous Metals, Nonferrous Metals, and Nonmetallic Minerals, Division of Production/Consumption Data Collection and Interpretation. Statistical data were compiled from information supplied by mineral producers, processors, and users in response to production and consumption canvasses, and their voluntary response is gratefully appreciated. The information obtained from individual firms by means of confidential surveys has been grouped to provide statistical aggregates. Data on individual firms are presented only if available from published or other nonconfidential sources or when permission of the companies has been granted. Other material appearing in this volume was obtained from the trade and technical press, industry contacts, and numerous other sources.

Statistics on U.S. imports and exports, world production, and foreign country trade were compiled in the Branch of Foreign Data. U.S. foreign trade data were obtained from reports of the Bureau of the Census, U.S. Department of Commerce. World production and international trade data came from numerous sources, including reports from the Foreign Service, U.S. Department of State.

The Branch of Publication Support Services, Division of Publication provided general guidance on the preparation and coordination of the chapters in this volume and reviewed the manuscripts to insure statistical consistency among the tables, figures, and text, between this volume and other volumes, and between this edition and those of former years.

Acknowledgment is also particularly made of the splendid cooperation of the business press, trade associations, scientific journals, international organizations, and other Federal agencies that supplied information.

The Bureau of Mines has been assisted in collecting mine production data and supporting information by numerous cooperating State agencies. These organizations are listed in the acknowledgments to Volume II.

Albert E. Schreck, *Editor-in-Chief*

Contents

Page
Foreword, by Lindsay D. Norman — iii
Acknowledgments, by Albert E. Schreck — v
Mining and quarrying trends in the metal and nonmetal industries, by Franklin D. Cooper — 1
Abrasive materials, by G. David Baskin — 27
Aluminum, by Horace F. Kurtz and Christine M. Moore — 43
Antimony, by T. John Rowland, Jr., and V. A. Cammarota, Jr. — 63
Asbestos, by R. A. Clifton — 71
Barite, by David E. Morse — 85
Bauxite and alumina, by Luke H. Baumgardner and Ruth A. Hough — 95
Beryllium, by Benjamin Petkof — 111
Bismuth, by James F. Carlin, Jr., and Robert J. Bascle — 115
Boron, by Sandra T. Absalom — 119
Bromine, by Sandra T. Absalom — 131
Cadmium, by John M. Lucas — 139
Calcium and calcium compounds, by J. W. Pressler — 147
Cement, by James T. Dikeou — 153
Chromium, by Norman A. Matthews and John L. Morning — 193
Clays, by Sarkis G. Ampian — 207
Cobalt, by Scott F. Sibley — 249
Columbium and tantalum, by Thomas S. Jones — 259
Copper, by James H. Jolly — 271
Diatomite, by A. C. Meisinger — 313
Feldspar, nepheline syenite, and aplite, by Michael J. Potter — 317
Ferroalloys, by Frederick J. Schottman — 327
Fluorspar, by Dennis S. Kostick and Ronald J. DeFilippo — 341
Gallium, by Benjamin Petkof — 359
Gem stones, by G. David Baskin — 363
Gold, by W. C. Butterman — 377
Graphite, by Harold A. Taylor, Jr. — 401
Gypsum, by J. W. Pressler — 411
Helium, by Russell J. Foster — 423
Iron ore, by E. C. Peterson and C. T. Collins — 433
Iron oxide pigments, by Cynthia T. Collins — 457
Iron and steel, by D. H. Desy — 465
Iron and steel scrap, by K. W. Palmer — 485
Kyanite and related materials, by Michael J. Potter — 503
Lead, by John A. Rathjen and T. John Rowland — 507

Page
Lime, by J. W. Pressler -- 539
Lithium, by Richard H. Singleton and James P. Searls ---------- 551
Magnesium, by Benjamin Petkof ---------------------------------- 559
Magnesium compounds, by Benjamin Petkof ------------------------ 567
Manganese, by Gilbert L. DeHuff -------------------------------- 577
Mercury, by Harold J. Drake ------------------------------------- 593
Mica, by Alvin B. Zlobik -- 601
Molybdenum, by John T. Kummer ---------------------------------- 615
Nickel, by Norman A. Matthews ---------------------------------- 629
Nitrogen, by Russell J. Foster --------------------------------- 643
Peat, by Richard H. Singleton and James P. Searls -------------- 655
Perlite, by A. C. Meisinger ------------------------------------ 671
Phosphate rock, by W. F. Stowasser ----------------------------- 677
Platinum-group metals, by James H. Jolly ----------------------- 699
Potash, by Richard H. Singleton and James P. Searls ------------ 713
Pumice and volcanic cinder, by A. C. Meisinger ----------------- 729
Rare-earth minerals and metals, by Christine M. Moore ---------- 735
Rhenium, by Larry J. Alverson ---------------------------------- 743
Salt, by Russell J. Foster ------------------------------------- 751
Sand and gravel, by Valentin V. Tepordei ----------------------- 763
Silicon, by Frederick J. Schottman and Peter H. Kuck ----------- 793
Silver, by Harold J. Drake -------------------------------------- 801
Slag—iron and steel, by Alvin B. Zlobik ------------------------- 821
Sodium and sodium compounds, by Dennis S. Kostick -------------- 835
Stone, by Richard H. Singleton ---------------------------------- 843
Sulfur and pyrites, by John E. Shelton ------------------------- 877
Talc and pyrophyllite, by Robert A. Clifton -------------------- 899
Thorium, by William S. Kirk ------------------------------------- 907
Tin, by James F. Carlin, Jr., and Keith L. Harris --------------- 915
Titanium, by Langtry E. Lynd and Ruth A. Hough ------------------ 933
Tungsten, by Philip T. Stafford -------------------------------- 949
Uranium (Depleted), by William S. Kirk ------------------------- 965
Vanadium, by George A. Morgan ---------------------------------- 969
Vermiculite, by A. C. Meisinger -------------------------------- 977
Zinc, by V. Anthony Cammarota, Jr., John M. Lucas, and Barbara M. Gorby -- 981
Zirconium and hafnium, by Langtry E. Lynd ---------------------- 1021
Minor metals (arsenic, cesium and rubidium, germanium, indium, radium, scandium, selenium, tellurium, thallium), by Staff, Section of Nonferrous Metals -- 1033
Minor nonmetals (asphalt (native), greensand, iodine, meerschaum, quartz crystal, staurolite, strontium, wollastonite, zeolites), by Staff, Section of Nonmetallic Minerals -- 1051

Mining and Quarrying Trends in the Metal and Nonmetal Industries

By Franklin D. Cooper[1]

The value of nonfuel mineral raw materials produced in the United States in 1978 was $20 billion. In 1979, total value increased to an estimated $24 billion, up 20% from 1978.

Of the principal metallic ores produced in 1979, about half showed increased quantitative output and all showed increased value per ton compared with that of 1978. Most nonmetallic commodities showed increases in quantitative output and in average value per ton.

Because of its decreasing share of the world market, the domestic mineral industry's concerns were the increasing costs of capital, labor, and energy; withdrawals of public lands from mining; and the increasing cost of environmental regulations that tended to deter or delay investment in the Nation's capacity for producing essential minerals.

In 1978, based on a survey of 64 mining and metals industries by Citibank, the rate of return on net worth in nonferrous metal manufacturing ranked 55th, nonmetal mining ranked 61st, and metal mining, 64th. The combined mining sector returned 8% of equity. Low profitability of some mining firms increased the cost of their borrowing and reduced the availability of funds except from banks at very high rates.

Pollution control expenditures in 1978 by the nonferrous metal industry equaled 12% of its total capital spending.

Legislation and Government Programs.—A 1979 Bureau of Land Management (BLM) inventory of 7,811 separate land withdrawals in the United States indicated that of the 67.9 million acres withdrawn, as required by the Federal Land Policy and Management Act, about 54.2 million acres were closed to mining under the general laws and 18.9 million acres were closed to leasing. Some withdrawals covered both locatable and leasable minerals.

The U.S. Department of the Interior (DOI) announced final approval of agreements with Montana, Utah, and Wyoming, permitting these States to supervise surface mining and reclamation on Federal lands within their borders.

DOI relaxed proposed restrictions for mineral development on 56.6 million acres of public land in Western States that could be turned into wilderness areas.

The primary conclusion of an 87-page report to Congress by the General Accounting Office (GAO) issued in late 1979 states that the cumulative effects of restrictive and contradictory Government policies and regulations are discouraging investment in U.S. mining and mineral processing and are forcing an increasing reliance on imported minerals.

Exploration and Development.—A University of Alaska report, issued in 1978, showed that 26% of the State's land area was open to mineral entry under Federal and State laws. Prospecting was permitted on 64 million acres of Federal lands and 36 million acres of State lands. New mining claims filed in 1978 totaled 18,500. Exploration in 1979 employed 1,700 persons and cost an estimated $75 million.

The uranium industry in 1978 spent $290 million for 52.5 million feet of exploration drilling in the United States.

The number of major companies reporting significant discoveries in 1978-79, according to the principal metal values found, were uranium, 13; molybdenum, 2; gold, 1; silver, 3; copper-nickel, 1; zinc-copper, 1; and lead-zinc-copper, 1.

Exploration was assisted by the increasing use of hydrostatic core drills, undeviating reaming shells in diamond drilling, a portable nondestructive analyzer, and dual-tube core barrels. The Bureau of Mines supported research on, and development of, a retractable coring bit.

Underground Mining.—Several raise boring records were made while developing ventilation and production shafts in salt, coal, and uranium mines.

The Bureau of Mines, by contracted or inhouse work, was active in the following: Demonstrating mechanical-impact breakers; building a 24-foot-diameter tunnel borer, an air-powered rig for drilling 36-foot probe holes, an exhaust muffler for old-model jumbo drills and diesel engines, trailing power cable reels, a low headroom portable crusher, a fire suppression system, roof warning devices, remotely powered roof supports, communication and surveillance systems, damage-resistant brattice and parachute stoppings, and in the testing of wooden props having a fire-resistant char covering, controlled yield rockbolts, lighting for jumbo drills, tamper-proof cassettes on personal dust monitors, and fiber-reinforced concrete cribbing to replace wood.

The Bureau described five methods for grounding power systems[4] and reviewed fire and smoke detection technology.[5] Dravo Corp. prepared a study for the Bureau titled, "Stope Mechanization in Vein Mining."

New equipment introduced by U.S. firms to reduce costs by increasing productivity included all-hydraulic long-hole drills for sublevel caving and stoping, 40-ton payload trucks for use on 10-foot-high haulageways, excavators to work in 5.5- to 16-square-foot tunnels, a 5-man escape hoist, a 50-watt high-pressure sodium light to replace conventional lighting, and a self-dumping roof-drill dust collector.

Drills with flat-faced carbide-button bits were increasingly used for 4- to 6-inch blastholes. Hydraulic drilling proved to have more productivity than pneumatic drilling.

Approximately 5,000 to 6,000 load-haul-dump (LHD) units in small hardrock mines displaced short-distance rail haulage systems. Rail haulage systems in the largest mines were equipped with remote-control locomotives, solid-state controls, silicon rectifiers and self-dumping cars. Two underground mines used 40-ton trucks for main-line haulage.

One mine used centrifuges underground to separate tailing slurry for backfilling materials.

The number of major mining equipment units in operation and the number of units sold annually for nonmetal mining are shown:

	Units in operation	Units sold annually
Electric motors	277,645	36,250
Diesel engines	183,595	22,950
Gasoline engines	126,620	15,830
Stationary air compressor	14,430	2,775
Portable air compressor	10,174	987
Conveyor belts	94,500	7,386
Crushers	32,391	3,279
Rotary drills	2,104	346
Front-end loaders	28,130	2,880
Pillow blocks	390,000	145,000
Portable washing, crushing, and screening plants	2,550	495
Water pumps	24,220	3,760
Vibrating screens	50,527	7,985
Tractors	11,245	3,285
On-highway trucks	91,519	11,919
Off-highway trucks	47,265	3,325
Pickup trucks	56,224	9,637

Source: Austin Powder Newsletter, July 9, 1979.

In Situ Mining.—The production of uranium-bearing slurries from unconsolidated ore was demonstrated using a Bureau-developed high-pressure water jet dimensioned for insertion in a borehole. One company used the jets in 42 wells in Texas. Three other companies in Texas and another in Wyoming also used jets.

In 1978, there were 8 active uranium in situ operations in Texas and 10 in Wyoming. In situ operations accounted for 2% of the total uranium production.

Andes Engineers International, Inc., proposed the creation of voids in a zone to be leached by leaving some drill holes open so that the ensuing blasted material could expand.

The Bureau of Mines developed a computer program for prediction of fluid flow during in situ mining.

Surface Mining.—New blasting laws and noise codes speeded the shift to smaller diameter drills.

One U.S. firm announced an electric rotary rig capable of angle-drilling 9- to 12-inch diameter holes. Ingersoll Rand offered two new Drillmasters for drilling 4.5- to 6.5-inch diameter holes 65 feet deep in one pass.

The Trojan Div., International Minerals and Chemical Corp. (Comsol) introduced a liquid fuel type blasting agent reportedly developing twice the explosive-state gas pressure of AN-FO.

Ten- to 25-cubic-yard electric, cable-crowd shovels handled most of the materials in open pits. Two U.S. firms introduced 25- to 28-cubic-yard electric shovels.

Two new makes of hydraulic shovels permitted their dippers to make long, flat passes in the bank toe.

An automatic fire-protection system, activated by heat sensors for discharging a dry chemical, was available for use on bulldozers.

Also introduced was a new "Auto-BELT" conveyor scale. Three copper pits in Arizona used conveyor-belt systems to handle 30,000 to 143,000 tons per day of ore and waste.

Three U.S. firms offered new computer-controlled systems for open pit materials handling.

R. A. Hanson Co. introduced a 500-ton-per-hour spreader stacker with a 150-foot telescoping conveyor.

Mechanical transmissions for trucks were preferred to electric drives having escalating capital operating and maintenance costs. Heavy-duty trucks featured constant-speed, variable-horsepower diesel engines instead of constant-horsepower, variable-speed engines.

The "Phase III" brake system was successfully demonstrated on loaded trucks in Arizona and Canada. An all-hydraulic braking system was tested on a prototype 100-ton rear-dump truck. The Bureau designed a mirror system to enlarge the field of vision for drivers of large trucks. A new one-piece rim-and-tire system was announced.

Beneficiation.—Increased attention in mineral processing was directed to physical and mechanical aspects rather than chemistry and surface phenomena.

Grinding performance was improved by better preparation of ore feed, by circuit controls, and by additives that shifted the electrochemical potentials of metallic grinding media from active to passive corroding.

One mill used automatic mantle positioning, by control of the hydraulic support pressure, on a tertiary crusher whose throughput was thereby increased 16%.

Lower capital and operating costs resulted from the use of horizontal belt filters as a substitute or adjunct to thickeners in a counter-current-decantation CCD circuit.

Towniprene lined flotation cells proved to be very resistant to abrasive slurries containing any combinations of five reagents.

A new 1,275-cubic-foot, mechanical-pneumatic flotation cell was introduced as was DAXAD (CP-1), a water-soluble, cationic polymer flocculant.

U.S. patent 4,165,279 was issued for a flotation cell having upright partition walls, froth generators below each partition, and rods of differential buoyancies in each cell to assure a predetermined froth thickness.

Tailings.—Bureau of Mines studies on tailings and slimes included: the wet high-intensity magnetic (WHIM) separation of nonmagnetic taconite tailings; the use of trommels to dewater phosphatic-clay slimes; the usefulness of a temporary stabilizing chemical at an active uranium-tailings pond; centrifuging of tailings; the use of a belt filter to produce a relatively dry solids cake; the production of ceramics and insulating materials; and the reduction of radon flux of tailings used for backfill in underground uranium mines.

A compact, 23-foot-diameter thickener at a zinc mill increased the tailing concentration threefold at an 800-gallon-per-minute flow rate.

New analytical devices available to mill operators included an optical sorter to distinguish valuable minerals in waste solids, a sturdy portable spectrometer, and a particle-size distribution transmitter.

Leaching.—Oxide copper heap leaching continued as in earlier years, and two sulfide operations were temporarily shut down in 1978.

Anamax Mining Co. operated a 10,000-ton-per-day leaching plant in Arizona where oxide was contacted with sulfuric acid, followed by decantation, thickening, solvent extraction, and electrowinning. Other companies continued dump and in situ leaching of oxide copper on a smaller scale.

The Anaconda Company closed its leach-precipitation operations at the Berkeley pit and Hecla/El Paso Mining Co. terminated sulfide roasting and leaching in Arizona.

Leaching research was done using ammonia in the presence of kerosine containing LIX63, and ammonia containing an organic sulfur content.

Pilot-scale leaching was done on uranium ores in Wyoming. The Bureau extracted low-grade laterite ore and used chlorine-hydrometallurgy to treat complex sulfide concentrates and smelter matte, and clays to absorb radium and thorium from waste uranium leach liquors.

Magnitude of the Mining Industry.—Compared with 1977 there were five fewer metal mines and 387 fewer nonmetal mines. Economics apparently were associated with these decreases primarily because it was less costly to expand an existing operation than to develop a new one.

Mines that produced in excess of 10 million short tons of crude ore comprised copper (11), iron ore (8), molybdenum (1), phosphate rock (6), sand and gravel (1), and stone (1). Total crude ore output (3.03 billion tons) and waste (1.59 billion tons) exceeded the respective 1977 tonnages.

In metal mining, United States Steel Corp.'s Minntac mine was the leading ore producer. Crude ore for nine metals and 21 nonmetals came entirely from surface mines in 24 States without using drilling or blasting.

Seven metal crude ores and eight nonmetal crude ores originated in both surface and underground mines. All lead and zinc ores came from underground mines, as did potassium salts, natural sodium carbonate (trona), and wollastonite.

Materials Handled.—Both metal and nonmetal mines handled more total materials in 1978 than in 1977. Crude ore equaled two-thirds of all materials handled by the nonfuel mining industry.

In underground metal mines, crude ore production remained unchanged although more waste was handled, while in nonmetal mines ore production was greater and waste production was significantly lower. Copper and iron ore mines collectively produced 83% of the crude ore and 72% of the total materials handled in metal mines.

In the nonmetal sector, phosphate rock, sand and gravel, and stone operations produced 94% of the crude ore and handled 59% of the total materials handled. Eleven States each accounted for at least 100 million tons of all materials handled.

Total Value Per Ton of Principal Mineral Products.—These values represent crude ore treated, or in the cases of nonmetals, crude ore shipped, and in some cases the total value includes that of byproducts. The total value for all mineral commodities increased 8% while that for byproducts remained unchanged.

Ratio of Treated Ore to Marketable Product.—The weight of crude ore treated to obtain one unit of marketable product in the metals ranged from 980:1 for uranium to 0.1:1.0 for silver. For most of the nonmetals, the ratio generally was 1.0:1.0.

Comparison of Products From Surface and Underground Mines.—As in previous years, there was little change in the ratio of crude ore mined and total materials handled in all surface and underground mines. Surface mines produced 94% of all ores and handled 96% of the related total materials handled. In nonmetals, surface mines produced 96% of the crude ore and handled 97% of all materials moved.

Exploration and Development.—Total footage drilled for exploration increased in 1978 as did development footage.

Increased activity in uranium in New Mexico and Wyoming resulted in significantly more exploration footage.

Rotary drilling accounted for by far the largest portion of exploration footage, which increased significantly for five metals and two nonmetals. A slight increase in diamond drilling was related to three metals and phosphate rock. Increased footage by churn drilling was indicated for lead and uranium, and silver exploration increased the footage for percussion drilling. More trenching was related to copper and lead exploration.

Development footage in metal mining was up by one-third compared with that of the previous year.

Explosives.—Metal mining and quarrying consumed 15% more explosives. Metal mining, principally in Arizona and New Mexico, predominately used water gels and slurries, while quarrying, mostly in Kentucky, Ohio, Pennsylvania, and Illinois, relied heavily on the use of high explosives.

More detailed explosives information may be found in the Annual Explosives issue of Mineral Industry Surveys prepared by the Bureau of Mines.

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[1] Physical scientist, Section of Ferrous Metals.

[2] Staff—Mining Research. Mine Power Systems Research (In Four Parts). 2. Grounding Research. BuMines IC 8800, 1979, 78 pp.

[3] Griffin, R. E. In-Mine Evaluation of Underground Fire and Smoke Detectors. BuMines IC 8808, 1979, 25 pp.

Table 1.—Material handled at surface and underground mines in the United States, by type

(Million short tons)

Type and year	Surface			Underground			All mines[1]		
	Crude ore	Waste	Total[1]	Crude ore	Waste	Total[1]	Crude ore	Waste	Total
Metals:									
1974	547	1,210	1,760	80	11	91	627	1,220	1,850
1975	535	1,170	1,700	74	13	87	609	1,180	1,790
1976	573	1,250	1,820	73	15	87	646	1,260	1,910
1977	490	1,040	1,530	74	12	87	564	1,050	1,610
1978	554	995	1,550	74	21	95	628	1,020	1,640
Nonmetals:									
1974	2,220	418	2,640	82	5	87	2,300	423	2,720
1975	1,910	372	2,290	79	6	84	1,990	378	2,370
1976	2,000	393	2,390	80	6	86	2,080	399	2,480
1977	2,120	472	2,590	80	6	86	2,200	478	2,680
1978	2,320	571	2,890	87	1	88	2,410	572	2,980
Total metals and nonmetals:[1]									
1974	2,760	1,630	4,390	162	16	178	2,930	1,650	4,570
1975	2,450	1,540	3,990	153	18	171	2,600	1,560	4,160
1976	2,570	1,640	4,210	153	21	174	2,720	1,660	4,390
1977	2,610	1,510	4,120	155	18	173	2,760	1,520	4,290
1978	2,870	1,570	4,440	161	22	183	3,030	1,590	4,620

[1] Data may not add to totals shown because of independent rounding.

Table 2.—Material handled at surface and underground mines in 1978, by commodity[1]

(Thousand short tons)

Commodity	Surface			Underground			All mines[2]		
	Crude ore	Waste	Total[2]	Crude ore	Waste	Total[2]	Crude ore	Waste	Total
METALS									
Bauxite	2,830	11,500	14,300	--	--	--	2,830	11,500	14,300
Copper	236,000	368,000	604,000	26,000	9,960	36,000	262,000	378,000	640,000
Gold:									
Lode	1,480	11,300	12,800	1,700	340	2,040	3,180	11,600	14,800
Placer	2,460	244	2,700	--	2	2	2,460	246	2,710
Iron ore	257,000	276,000	534,000	5,030	448	5,480	262,000	277,000	539,000
Lead	--	1	1	9,580	2,270	11,800	9,580	2,270	11,800
Silver	685	1,310	2,000	1,150	698	1,850	1,840	2,010	3,840
Titanium, ilmenite	29,200	3,610	32,800	--	--	--	29,200	3,610	32,800
Tungsten	31	10	41	806	200	1,010	837	210	1,050
Uranium	10,200	300,000	310,000	6,250	5,370	11,600	16,500	306,000	322,000
Zinc	W	W	W	6,400	1,270	7,670	6,400	1,270	7,670
Other[3]	14,100	22,800	36,900	17,100	400	17,500	31,200	23,200	54,400
Total metals[2]	554,000	995,000	1,550,000	74,000	21,000	95,000	628,000	1,020,000	1,640,000
NONMETALS									
Abrasives[4]	319	66	385	W	--	W	319	66	385
Asbestos	2,260	4,150	6,410	W	W	W	2,260	4,150	6,410
Barite	4,660	495	5,160	--	--	--	4,660	495	5,160
Clays	49,500	^{e}43,000	92,500	2,800	^{e}39	2,840	52,300	^{e}43,000	95,300
Diatomite	710	--	710	--	--	--	710	--	710
Feldspar	1,480	192	1,680	W	--	W	1,480	192	1,680
Fluorspar	19	20	39	428	56	485	448	76	524
Gypsum	12,900	2,700	15,600	2,530	--	2,530	15,500	2,700	18,200
Mica (scrap)	1,540	467	2,010	--	--	--	1,540	467	2,010
Perlite	934	107	1,040	5	--	5	939	107	1,050
Phosphate rock	191,000	420,000	611,000	W	W	W	191,000	420,000	611,000
Potassium salts	--	--	--	19,300	163	19,500	19,300	163	19,500
Pumice	4,590	108	4,700	--	--	--	4,590	108	4,700

Salt	3,580	--	3,580	14,600	--	14,600	18,200	--	18,200
Sand and gravel	997,000	--	997,000	--	--	--	997,000	--	997,000
Sodium carbonate (natural)	--	--	--	11,200	332	11,500	11,200	332	11,500
Stone:									
Crushed and broken	1,040,000	e82,200	1,120,000	35,700	e248	35,900	1,070,000	e82,400	1,150,000
Dimension	4,200	e1,620	5,830	W	--	W	4,200	e1,620	5,830
Talc, soapstone, pyrophyllite	1,150	1,450	2,600	358	8	366	1,510	1,460	2,970
Other[5]	6,040	14,600	20,000	382	20	400	6,420	14,600	21,000
Total nonmetals[2]	2,820,000	571,000	2,890,000	87,300	962	88,200	2,410,000	572,000	2,980,000
Grand total[2]	2,870,000	1,570,000	4,440,000	161,000	21,800	183,000	3,080,000	1,590,000	4,620,000

[e] Estimate.   W Withheld to avoid disclosing company proprietary data; included in "Other."

[1] Excludes material from wells, ponds, or pumping operations.

[2] Data may not add to totals shown because of independent rounding.

[3] Antimony, beryllium, manganiferous ore, mercury, molybdenum, nickel, rare-earth metals, tin, and vanadium.

[4] Emery, garnet, and tripoli.

[5] Aplite, boron minerals, graphite, greensand marl, iron oxide pigments (crude), kyanite, lithium minerals, magnesite, millstones, olivine, tube-mill liners, vermiculite, wollastonite, and quantity of metal and nonmetal items indicated by symbol W.

Table 3.—Material handled at surface and underground mines (including sand and gravel and stone) in 1978, by State[1]

(Thousand short tons)

State	Surface			Underground			All mines[2]		
	Crude ore	Waste	Total[3]	Crude ore	Waste	Total[3]	Crude ore	Waste	Total
Alabama	45,300	6,210	51,500	W	W	W	45,300	6,210	51,500
Alaska	74,900	483	75,400	(4)	--	(4)	74,900	483	75,400
Arizona	193,000	228,000	420,000	20,600	9,450	30,100	214,000	237,000	451,000
Arkansas	40,400	13,500	53,900	W	W	W	40,400	13,500	53,900
California	173,000	57,000	230,000	1,200	79	1,280	174,000	57,100	231,000
Colorado	40,000	16,000	56,000	18,400	1,550	19,900	58,400	17,600	76,000
Connecticut	18,600	730	19,400	--	--	--	18,600	730	19,400
Delaware	1,460	9	1,470	--	--	--	1,460	9	1,470
Florida	272,000	340,000	612,000	73	1	74	272,000	340,000	612,000
Georgia	54,500	10,200	64,700	1,960	23	1,980	56,500	10,200	66,700
Hawaii	7,010	494	7,500	--	--	--	7,010	494	7,500
Idaho	17,800	34,700	52,400	1,650	339	1,990	19,400	35,000	54,400
Illinois	105,000	5,600	110,000	2,660	65	2,720	107,000	5,660	113,000
Indiana	61,900	3,680	65,600	2,020	6	2,020	63,900	3,690	67,600
Iowa	49,700	2,930	52,700	1,900	11	1,910	51,600	2,940	54,600
Kansas	33,200	2,160	35,400	3,020	13	3,040	36,200	2,180	38,400
Kentucky	47,000	3,430	50,400	7,800	61	7,860	54,800	3,490	58,300
Louisiana	31,900	1,160	33,000	6,350	--	6,350	38,200	1,160	39,400
Maine	13,300	222	13,500	--	--	--	13,300	222	13,500
Maryland	33,600	2,280	35,900	W	W	W	33,600	2,280	35,900
Massachusetts	26,700	904	27,600	--	--	--	26,700	904	27,600
Michigan	142,000	59,900	202,000	6,510	30	6,540	149,000	59,900	208,000
Minnesota	230,000	171,000	401,000	--	--	--	230,000	171,000	401,000
Mississippi	20,300	1,860	22,100	W	W	W	20,300	1,860	22,100
Missouri	68,000	5,150	73,100	18,300	2,610	20,900	86,200	7,760	94,000
Montana	28,400	1,060	29,500	395	44	439	28,800	1,110	29,900
Nebraska	20,900	356	21,200	W	W	W	20,900	356	21,200
Nevada	22,900	24,800	47,700	262	173	435	23,100	25,000	48,100
New Hampshire	8,930	168	9,100	--	--	--	8,930	168	9,100
New Jersey	31,900	1,140	33,100	207	(4)	207	32,100	1,140	33,300
New Mexico	39,700	167,000	207,000	23,600	1,780	25,400	63,300	169,000	232,000
New York	66,100	4,470	70,600	4,230	63	4,290	70,400	4,540	74,900

North Carolina	64,300	48,100	112,000	--	--	--	64,300	48,100	112,000
North Dakota	7,580	84	7,670	--	--	--	7,580	84	7,670
Ohio	101,000	6,720	108,000	3,970	9	3,980	105,000	6,720	112,000
Oklahoma	40,900	2,580	43,500	W	W	W	40,900	2,580	43,500
Oregon	40,900	3,140	44,000	3	2	5	40,900	3,140	44,000
Pennsylvania	88,700	7,500	96,200	3,800	51	3,850	92,500	7,550	100,000
Rhode Island	3,280	25	3,300	--	--	--	3,280	25	3,300
South Carolina	27,900	2,970	30,900	W	W	W	27,900	2,970	30,900
South Dakota	10,500	581	11,100	W	W	W	10,500	581	11,100
Tennessee	59,900	13,500	73,400	8,480	1,130	9,610	68,400	14,600	83,000
Texas	136,000	88,700	225,000	596	3	599	137,000	88,700	226,000
Utah	57,600	8,100	65,700	1,170	1,350	2,520	58,800	9,450	68,200
Vermont	7,130	1,570	8,700	206	--	206	7,340	1,570	8,900
Virginia	61,700	4,900	66,600	2,640	23	2,660	64,300	4,930	69,300
Washington	33,400	13,500	46,900	W	W	W	33,400	13,500	46,900
West Virginia	14,100	1,160	15,200	2,710	21	2,730	16,800	1,180	18,000
Wisconsin	57,200	9,300	66,500	W	W	W	57,200	9,300	66,500
Wyoming	20,300	185,000	205,000	13,300	2,650	15,900	33,600	188,000	221,000
Undistributed	20,200	1,900	22,100	3,430	274	3,700	23,600	2,200	25,800
Total[3] [4]	2,870,000	1,570,000	4,440,000	161,000	21,800	183,000	3,030,000	1,590,000	4,620,000

W Withheld to avoid disclosing company proprietary data; included with "Undistributed."

[1] Excludes material from wells, ponds, or pumping operations.

[2] Data may not add to totals shown because of independent rounding.

[3] Less than 1/2 unit.

[4] Includes estimated data in table 2.

Table 4.—Value of principal mineral products and byproducts of surface and underground ores mined in the United States in 1978

(Value per ton)

Ore	Surface			Underground			All mines		
	Principal mineral product	By-product	Total	Principal mineral product	By-product	Total	Principal mineral product	By-product	Total
METALS									
Bauxite	$7.07	$12.79	$19.86	--	--	--	$7.07	$12.79	$19.86
Copper	7.02	1.31	8.33	$12.11	$2.61	$14.72	7.53	1.44	8.97
Gold:									
Lode	27.96	.54	28.50	40.44	1.86	42.30	35.38	1.33	36.71
Placer	1.75	--	1.75	--	--	--	1.75	--	1.75
Iron ore	8.84	--	8.84	16.14	.36	16.50	8.98	.01	8.99
Lead	--	--	--	37.67	9.14	46.81	37.67	9.14	46.81
Silver	14.68	4.87	19.55	88.44	23.66	112.10	60.23	16.47	76.70
Titanium, ilmenite	.90	.62	1.52	--	--	--	.90	.62	1.52
Tungsten	21.69	--	21.69	44.67	1.13	45.80	43.90	1.09	44.99
Uranium	33.98	--	33.98	57.76	7.79	65.55	42.86	2.91	45.77
Zinc	--	--	--	21.58	5.82	27.40	21.58	5.82	27.40
Average[1]	8.43	.69	9.12	21.64	3.70	25.34	9.99	1.05	11.04
NONMETALS									
Asbestos	12.08	--	12.08	W	--	W	12.08	--	12.08
Barite	9.41	.01	9.42	--	--	--	9.41	.01	9.42
Clays	10.94	--	10.94	43.85	--	43.85	12.70	--	12.70
Diatomite	110.05	--	110.05	--	--	--	110.05	--	110.05
Feldspar	9.02	1.31	10.33	W	--	W	9.02	1.31	9.02
Fluorspar	30.11	--	30.11	29.50	5.05	34.55	29.53	4.83	34.36
Gypsum	5.81	.15	5.96	6.64	--	6.64	5.95	.13	6.08
Mica (scrap)	5.04	.89	5.93	--	--	--	5.04	.89	5.93
Perlite	14.70	--	14.70	.71	--	.71	13.53	--	13.53
Phosphate rock	4.84	.05	4.89	W	--	W	4.84	.05	4.89
Potassium salts	--	--	--	9.52	.07	9.59	9.52	.07	9.59
Pumice	2.91	--	2.91	--	--	--	2.91	--	2.91
Salt	41.21	5.04	46.25	10.07	1.65	11.72	16.18	2.31	18.49
Sand and gravel	2.26	.08	2.29	--	--	--	2.26	.08	2.29
Sodium carbonate (natural)	--	--	--	30.42	--	30.42	30.42	--	30.42

Stone:									
Crushed and broken	2.66	.02	2.68	3.29	--	3.29	2.66	.02	2.68
Dimension	79.18	.16	79.34	W	--	W	79.18	.16	79.34
Talc, soapstone, pyrophyllite	7.52	--	7.52	13.67	--	13.67	8.78	--	8.78
Average[1]	3.16	.04	3.20	11.07	.32	11.39	3.45	.05	3.50
Average, metals and nonmetals[1]	4.18	.16	4.34	15.92	1.87	17.79	4.80	.26	5.06
Average, nonmetals (excluding stone and sand and gravel)[1]	7.88	.12	8.00	16.33	.53	16.86	9.20	.19	9.39
Average, metals and nonmetals, (excluding stone and sand and gravel)[1]	8.25	.50	8.75	19.45	2.39	21.84	9.72	.75	10.47

W Withheld to avoid disclosing company proprietary data.

[1] Includes unpublished data.

Table 5.—Crude ore and total material handled at surface and underground mines in 1978, by commodity

(Percent)

Commodity	Crude ore		Total material	
	Surface	Underground	Surface	Underground
METALS				
Antimony	--	100	--	100
Bauxite	100	--	100	--
Beryllium	100	--	100	--
Copper	90	10	94	6
Gold:				
Lode	46	54	86	14
Placer	100	--	100	--
Iron ore	98	2	99	1
Lead	--	100	--	100
Manganiferous ore	100	--	100	--
Mercury	100	--	100	--
Molybdenum	37	63	61	39
Nickel	100	--	100	--
Rare-earth metals	100	--	100	--
Silver	37	63	52	48
Tin	100	--	100	--
Titanium, ilmenite	100	--	100	--
Tungsten	4	96	4	96
Uranium	62	38	96	4
Vanadium	100	--	100	--
Zinc	--	100	W	[1]100
Total metals	88	12	94	6
NONMETALS				
Aplite	100	--	100	--
Asbestos	[1]100	W	[1]100	W
Barite	100	--	100	--
Boron minerals	100	--	100	--
Clays	95	5	97	3
Diatomite	100	--	100	--
Emery	100	--	100	--
Feldspar	[1]100	W	[1]100	W
Fluorspar	4	96	8	92
Garnet	100	--	100	--
Graphite	100	--	100	--
Greensand marl	100	--	100	--
Gypsum	84	16	86	14
Iron oxide pigments (crude)	100	--	100	--
Kyanite	100	--	100	--
Lithium minerals	100	--	100	--
Magnesite	100	--	100	--
Mica (scrap)	100	--	100	--
Millstones	100	--	100	--
Olivine	100	--	100	--
Perlite	[1]100	W	[1]100	W
Phosphate rock	[1]100	W	[1]100	W
Potassium salts	--	100	--	100
Pumice	100	--	100	--
Salt	20	80	20	80
Sand and gravel	100	--	100	--
Sodium carbonate (natural)	--	100	--	100
Stone:				
Crushed and broken	97	3	97	3
Dimension	[1]100	W	[1]100	W
Talc, soapstone, pyrophyllite	76	24	88	12
Tripoli	[1]100	W	[1]100	W
Vermiculite	100	--	100	--
Wollastonite	W	[2]100	W	[2]100
Total nonmetals	96	4	97	3
Grand total	95	5	96	4

W Withheld to avoid disclosing company proprietary data; included with "Surface."

[1] Includes underground; the Bureau of Mines is not at liberty to publish separately.

[2] Includes surface; the Bureau of Mines is not at liberty to publish separately.

Table 6.—Crude ore and total material handled at surface and underground mines in 1978, by State

(Percent)

State	Crude ore		Total material	
	Surface	Underground	Surface	Underground
Alabama	[1]100	W	[1]100	W
Alaska	100	--	100	--
Arizona	90	10	93	7
Arkansas	[1]100	W	[1]100	W
California	99	1	99	1
Colorado	68	32	74	26
Connecticut	100	--	100	--
Delaware	100	--	100	--
Florida	100	--	100	--
Georgia	96	4	97	3
Hawaii	100	--	100	--
Idaho	91	9	96	4
Illinois	97	3	98	2
Indiana	97	3	97	3
Iowa	96	4	96	4
Kansas	92	8	92	8
Kentucky	86	14	86	14
Louisiana	83	17	84	16
Maine	100	--	100	--
Maryland	[1]100	W	[1]100	W
Massachusetts	100	--	100	--
Michigan	96	4	97	3
Minnesota	100	--	100	--
Mississippi	[1]100	W	100	W
Missouri	79	21	78	22
Montana	99	1	98	2
Nebraska	[1]100	W	[1]100	W
Nevada	99	1	99	1
New Hampshire	100	--	100	--
New Jersey	99	1	99	1
New Mexico	63	37	89	11
New York	94	6	94	6
North Carolina	100	--	100	--
North Dakota	100	--	100	--
Ohio	96	4	96	4
Oklahoma	[1]100	W	[1]100	W
Oregon	100	--	100	--
Pennsylvania	96	4	96	4
Rhode Island	100	--	100	--
South Carolina	[1]100	W	[1]100	W
South Dakota	[1]100	W	[1]100	W
Tennessee	88	12	88	12
Texas	100	--	100	--
Utah	98	2	96	4
Vermont	97	3	98	2
Virginia	96	4	96	4
Washington	[1]100	W	[1]100	W
West Virginia	84	16	85	15
Wisconsin	[1]100	W	[1]100	W
Wyoming	60	40	93	7
Total	95	5	96	4

W Withheld to avoid disclosing company proprietary data; included with "Surface."

[1] Includes underground; the Bureau of Mines is not at liberty to publish separately.

Table 7.—Number of domestic metal and nonmetal mines in 1978, by commodity and magnitude of crude ore production[1]

Commodity	Total number of mines	Less than 1,000 tons	1,000 to 10,000 tons	10,000 to 100,000 tons	100,000 to 1,000,000 tons	1,000,000 to 10,000,000 tons	More than 10,000,000 tons
METALS							
Bauxite	12	--	--	5	7	--	--
Copper	32	1	--	3	4	13	11
Gold:							
Lode	49	31	5	8	4	1	--
Placer	37	7	9	18	2	1	--
Iron ore	48	--	3	7	13	17	8
Lead	23	7	4	2	5	5	--
Silver	45	25	8	7	5	--	--
Titanium, ilmenite	7	--	--	--	2	5	--
Tungsten	65	51	9	3	2	--	--
Uranium	271	43	99	84	43	2	--
Zinc	26	1	4	6	15	--	--
Other[2]	12	2	--	3	3	3	1
Total metals	627	168	141	146	105	47	20
NONMETALS							
Abrasives[3]	13	2	4	6	1	--	--
Asbestos	4	--	--	2	1	1	--
Barite	30	--	5	14	11	--	--
Boron minerals	3	1	--	--	1	1	--
Clays	1,125	55	244	670	156	--	--
Diatomite	13	--	6	5	2	--	--
Feldspar	18	1	3	6	3	--	--
Fluorspar	7	--	4	1	2	--	--
Gypsum	69	1	6	17	44	1	--
Mica (scrap)	16	1	1	7	7	--	--
Perlite	12	--	4	5	3	--	--
Phosphate rock	45	--	4	5	13	17	6
Potassium salts	8	--	--	--	2	6	--
Pumice	205	11	97	91	6	--	--
Salt	31	1	2	5	16	7	--
Sand and gravel	7,259	97	1,206	3,370	2,490	95	1
Sodium carbonate (natural)	4	--	--	--	--	4	--
Stone:							
Crushed and broken	4,455	218	610	1,697	1,718	211	1
Dimension	373	106	170	88	9	--	--
Talc, soapstone, pyrophyllite	43	4	15	19	5	--	--
Other[4]	32	6	8	10	8	--	--
Total nonmetals	13,765	504	2,389	6,018	4,503	343	8
Grand total	14,392	672	2,530	6,164	4,608	390	28

[1] Excludes wells, ponds, or pumping operations.

[2] Antimony, manganiferous ore, mercury, molybdenum, nickel, rare-earth metals, tin, and vanadium.

[3] Emery, garnet, and tripoli.

[4] Aplite, graphite, greensand marl, iron oxide pigments (crude), kyanite, lithium minerals, magnesite, millstones, olivine, tube-mill liners, vermiculite, and wollastonite.

Table 8.—Twenty-five leading metal and nonmetal[1] mines in the United States in 1978, in order of output of crude ore

Mine	State	Operator	Commodity	Mining method
		METALS		
Minntac	Minnesota	United States Steel Corp	Iron ore	Open pit.
Utah Copper	Utah	Kennecott Copper Corp	Copper	Do.
Sierrita	Arizona	Duval Sierrita Corp	do	Do.
Peter Mitchell	Minnesota	Reserve Mining Co	Iron ore	Do.
Erie Commercial	do	Pickands Mather & Co	do	Do.
San Manuel	Arizona	Magma Copper Co	Copper	Do.
Morenci	do	Phelps Dodge Corp	do	Do.
Berkeley Pit	Montana	The Anaconda Company	do	Do.
Empire	Michigan	Cleveland-Cliffs Iron Co	Iron ore	Do.
Hibbing Taconite	Minnesota	Pickands Mather & Co	do	Do.
Climax	Colorado	Climax Molybdenum Co., a division of Amax Inc.	Molybdenum	Caving and open pit.
Pinto Valley	Arizona	Cities Service Co	Copper	Open pit.
Thunderbird	Minnesota	Oglebay Norton Co	Iron ore	Do.
Tyrone	New Mexico	Phelps Dodge Corp	Copper	Do.
National Pellet Project	Minnesota	Hanna Mining Co	Iron ore	Do.
Bagdad	Arizona	Cyprus-Bagdad Copper Co	Copper	Do.
Tilden	Michigan	Cleveland-Cliffs Iron Co	Iron ore	Do.
Ray Pit	Arizona	Kennecott Copper Corp	Copper	Do.
Metcalf	do	Phelps Dodge Corp	do	Do.
Twin Buttes	do	Anamax Mining Co	do	Do.
Butler Project	Minnesota	Hanna Mining Co	Iron ore	Do.
New Cornelia	Arizona	Phelps Dodge Corp	Copper	Do.
Inspiration	do	Inspiration Consolidated Copper Corp.	do	Do.
Republic	Michigan	Cleveland-Cliffs Iron Co	Iron ore	Do.
Lakehurst	New Jersey	ASARCO Incorporated	Titanium	Dredging.
		NONMETALS		
Noralyn	Florida	International Minerals & Chemical Corp.	Phosphate rock.	Open pit.
Kingsford	do	do	do	Do.
Suwannee	do	Occidental Petroleum Corp	do	Do.
Ft. Green	do	Williams Co	do	Do.
Ft. Meade	do	Mobil Oil Corp	do	Do.
Calcite	Michigan	United States Steel Corp	Stone	Open quarry.
Payne Creek	Florida	Williams Co	Phosphate rock.	Open pit.
Clear Spring	do	International Minerals & Chemical Corp.	do	Do.
Haynsworth	do	American Cyanamid Co	do	Do.
Thornton	Illinois	General Dynamics Corp	Stone	Open quarry.
Feld	Texas	Texas Crushed Stone Co	do	Open pit.
Lee Creek	North Carolina	Texasgulf, Inc	Phosphate rock.	Do.
Ft. Meade	Florida	Gardinier, Inc	do	Do.
Stoneport	Michigan	Presque Isle Corp	Stone	Open quarry.
Hookers	Florida	W. R. Grace & Co	Phosphate rock.	Open pit.
Lonesome	do	American Cyanamid Co	do	Do.
Nichols	do	Mobil Oil Corp	do	Do.
Big Four	do	Borden, Inc	do	Do.
Rockland	do	United States Steel Corp	do	Do.
Silver City	do	Estech General Chemical Corp	do	Do.
International	New Mexico	International Minerals & Chemical Corp.	Potassium salts.	Open stopes.
Granite Mountain	Arkansas	McGeorge Contractor Co., Inc	Stone	Open quarry.
FEC Hialea	Florida	Rinker Materials Corp	do	Do.
Bonny Lake	do	W. R. Grace & Co	Phosphate rock.	Open pit.
Westvaco	Wyoming	FMC Corp	Sodium	Artificial stopes.

[1] Brines and materials from wells excepted.

Table 9.—Twenty-five leading metal and nonmetal[1] mines in the United States in 1978, in order of output of total materials handled

Mine	State	Operator	Commodity	Mining method
		METALS		
Tyrone	New Mexico	Phelps Dodge Corp	Copper	Open pit.
Minntac	Minnesota	United States Steel Corp	Iron ore	Do.
Sierrita	Arizona	Duval Sierrita Corp	Copper	Do.
Hibbing Taconite	Minnesota	Pickands Mather & Co.	Iron ore	Do.
Conquista	Texas	Continental Oil Co	Uranium	Do.
Empire	Michigan	Cleveland-Cliffs Iron Co	Iron ore	Do.
Morenci	Arizona	Phelps Dodge Corp	Copper	Do.
Shirley Basin	Wyoming	Utah International, Inc	Uranium	Do.
Highland	do	Exxon Corp	do	Do.
Erie Commercial	Minnesota	Pickands Mather & Co.	Iron ore	Do.
Pinto Valley	Arizona	Cities Service Co	Copper	Do.
Shirley	Wyoming	Getty Oil Co	Uranium	Do.
Eagle Mountain	California	Kaiser Steel Corp	Iron ore	Do.
Mitchell Pit	Minnesota	Reserve Mining Co	do	Do.
Bagdad	Arizona	Cyprus Bagdad Copper Co.	Copper	Do.
Utah Copper	Utah	Kennecott Copper Corp	do	Do.
Jackpile-Paquate	New Mexico	The Anaconda Company	Uranium	Do.
Twin Buttes	Arizona	Anamax Mining Co	Copper	Do.
Climax	Colorado	Climax Molybdenum Co., a division of Amax, Inc.	Molybdenum	Caving and open pit.
Chino	New Mexico	Kennecott Copper Corp	Copper	Open pit.
Metcalf	Arizona	Phelps Dodge Corp	do	Do.
Mission	do	ASARCO, Incorporated	do	Do.
Tilden	Michigan	Cleveland-Cliffs Iron Co	Iron ore	Do.
San Manuel	Arizona	Magma Copper Co	Copper	Caving.
Bear Creek	Wyoming	Rocky Mountain Energy Co.	Uranium	Open pit.
		NONMETALS		
Kingsford	Florida	International Minerals & Chemical Corp.	Phosphate rock.	Open pit.
Ft. Green	do	Williams Co	do	Do.
Lee Creek	North Carolina	Texasgulf Inc	do	Do.
Noralyn	Florida	International Minerals & Chemical Corp.	do	Do.
Suwannee	do	Occidental Petroleum Corp.	do	Do.
Payne Creek	do	Williams Co	do	Do.
Haynsworth	do	American Cyanamid Co	do	Do.
Big Four	do	Borden, Inc	do	Do.
Clear Spring	do	International Minerals & Chemical Corp.	do	Do.
Ft. Meade	do	Mobil Oil Corp	do	Do.
Lonesome	do	American Cyanamid Co	do	Do.
Bonny Lake	do	W. R. Grace & Co	do	Do.
Rockland	do	United States Steel Corp	do	Do.
Ft. Mead	do	Gardinier, Inc	do	Do.
Hookers	do	W. R. Grace & Co	do	Do.
Watson	do	Estech General Chemical Corp	do	Do.
Nichols	do	Mobil Oil Corp	do	Do.
Silver City	do	Estech General Chemical Corp	do	Do.
Boron	California	U.S. Borax & Chemical Corp	Boron minerals	Do.
Calcite	Michigan	United States Steel Corp	Stone	Open quarry.
Thornton	Illinois	General Dynamics Corp	do	Do.
Mable Canyon	Idaho	Conda Partnership	Phosphate rock	Open pit.
Feld	Texas	Texas Crushed Stone Co.	Stone	Open quarry.
Wooley Valley	Idaho	Stauffer Chemical Co	Phosphate rock.	Open pit.
Gay	do	J. R. Simplot Co	do	Do.

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[1] Brines and materials from wells excepted.

Table 10.—Ore treated or sold per unit of marketable product at surface and underground mines in the United States in 1978, by commodity

Commodity	Unit of marketable product	Surface: Ore treated (thousand short tons)	Surface: Marketable product (units)	Surface: Ratio of units of ore to units of marketable product	Underground: Ore treated (thousand short tons)	Underground: Marketable product (units)	Underground: Ratio of units of ore to units of marketable product	Total[1]: Ore treated (thousand short tons)	Total[1]: Marketable product (units)	Total[1]: Ratio of units of ore to units of marketable product
METALS										
Bauxite	thousand long tons	3,280	1,640	2.0:1	--	--	--	3,280	1,640	2.0:1
Copper	thousand short tons	235,000	1,240	189.4:1	26,100	238	109.9:1	261,000	1,480	176.6:1
Gold:										
Lode	thousand troy ounces	1,190	172	6.9:1	1,750	365	4.8:1	2,940	537	5.5:1
Placer	do	2,460	22	110.2:1	--	--	--	2,460	22	110.8:1
Iron ore	thousand long tons	260,000	79,600	3.3:1	5,090	2,970	1.7:1	266,000	82,600	3.2:1
Lead	thousand short tons	--	--	--	9,430	527	17.9:1	9,430	527	17.9:1
Silver	thousand troy ounces	726	1,970	.4:1	1,170	19,200	.1:1	1,900	21,200	.1:1
Titanium, ilmenite	thousand short tons	28,500	581	49.1:1	--	--	--	28,500	581	49.1:1
Uranium	do	10,200	8	1,236.0:1	6,070	8	727.4:1	16,200	17	980.0:1
Zinc	do	W	W	W	6,900	240	28.7:1	6,900	240	28.7:1
NONMETALS										
Asbestos	do	2,280	102	22.4:1	W	W	W	2,280	102	22.4:1
Barite	do	4,660	2,110	2.2:1	--	--	--	4,660	2,110	2.2:1
Clays	do	49,500	49,500	1.0:1	2,800	2,800	1.0:1	52,300	52,300	1.0:1
Diatomite	do	658	651	1.0:1	--	--	--	658	651	1.0:1
Feldspar	do	1,520	600	2.5:1	W	W	W	1,520	600	2.5:1
Fluorspar	do	20	10	1.9:1	429	119	3.6:1	449	129	3.5:1
Gypsum	do	13,100	12,600	1.0:1	2,530	2,290	1.1:1	15,600	14,900	1.1:1
Mica (scrap)	do	1,460	150	9.7:1	--	--	--	1,460	150	9.7:1
Perlite	do	930	636	1.5:1	W	W	W	930	636	1.5:1
Phosphate rock	do	191,000	55,000	3.5:1	W	W	W	191,000	55,000	3.5:1
Potassium salts	do	--	--	--	19,300	2,140	9.0:1	19,300	2,140	9.0:1

See footnotes at end of table.

Table 10.—Ore treated or sold per unit of marketable product at surface and underground mines in the United States in 1978, by commodity —Continued

Commodity	Unit of marketable product	Surface			Underground			Total[1]		
		Ore treated (thousand short tons)	Marketable product (units)	Ratio of units of ore to units of marketable product	Ore treated (thousand short tons)	Marketable product (units)	Ratio of units of ore to units of marketable product	Ore treated (thousand short tons)	Marketable product (units)	Ratio of units of ore to units of marketable product
NONMETALS —Continued										
Pumice	do	4,970	4,760	1.0:1	--	--	--	4,970	4,760	1.0:1
Salt	do	3,610	2,870	1.3:1	14,800	14,500	1.0:1	18,400	17,300	1.1:1
Sand and gravel	do	996,000	990,000	1.0:1	--	--	--	996,000	990,000	1.0:1
Sodium carbonate (natural)	do	--	--	--	11,600	6,520	1.8:1	11,600	6,520	1.8:1
Stone:										
Crushed and broken	do	1,040,000	1,030,000	1.0:1	35,700	35,100	1.0:1	1,070,000	1,070,000	1.0:1
Dimension	do	*4,200	1,390	3.0:1	W	W	W	*4,220	1,390	3.0:1
Talc, soapstone, pyrophyllite	do	1,390	976	1.4:1	350	352	1.0:1	1,750	1,330	1.3:1

*Estimate. W Withheld to avoid disclosing company proprietary data.

[1] Data may not add to totals shown because of independent rounding.

Table 11.—Material handled per unit of marketable product at surface and underground mines in the United States in 1978, by commodity

Commodity	Unit of marketable product	Surface			Underground			Total[1]		
		Total material handled[2] (thousand short tons)	Marketable product (units)	Ratio of units of material handled to units of marketable product[3]	Total material handled[2] (thousand short tons)	Marketable product (units)	Ratio of units of material handled to units of marketable product[3]	Total material handled[2] (thousand short tons)	Marketable product (units)	Ratio of units of material handled to units of marketable product[3]
METALS										
Bauxite	thousand long tons	14,300	1,640	8.6:1	--	--	--	14,300	1,640	8.6:1
Copper	thousand short tons	604,000	1,240	436.2:1	36,000	238	110.5:1	40,000	1,480	383.9:1
Gold:										
Lode	thousand troy ounces	13,000	172	36.9:1	2,040	365	5.1:1	15,000	537	15.3:1
Placer	do	2,710	22	111.9:1	(4)	--	.0:1	2,710	22	111.9:1
Iron ore	thousand long tons	524,000	79,600	5.6:1	5,430	2,970	1.7:1	529,000	82,600	5.4:1
Lead	thousand short tons	(4)	--	.0:1	11,800	527	19.1:1	11,800	527	19.1:1
Silver	thousand troy ounces	2,000	1,970	.4:1	1,850	19,200	.1:1	3,840	21,200	.1:1
Titanium, ilmenite	thousand short tons	32,800	581	56.5:1	--	--	--	32,800	581	56.5:1
Uranium	do	310,000	8	24,663.7:1	11,600	8	901.8:1	322,000	17	12,703.9:1
Zinc	do	W	W	W	7,670	240	27.3:1	7,670	240	27.3:1
NONMETALS										
Asbestos	do	6,410	102	34.5:1	W	W	W	6,440	102	34.5:1
Barite	do	5,160	2,110	2.4:1	--	--	--	5,160	2,110	2.4:1
Clays	do	[e]92,500	49,500	1.9:1	[e]2,840	2,800	1.0:1	[e]95,300	52,300	1.8:1
Diatomite	do	710	651	1.1:1	--	--	--	710	651	1.1:1
Feldspar	do	1,680	600	2.8:1	W	W	W	1,680	600	2.8:1
Fluorspar	do	39	10	1.9:1	485	119	3.6:1	524	129	3.5:1
Gypsum	do	15,600	12,600	1.2:1	2,530	2,290	1.1:1	18,200	14,900	1.2:1
Mica (scrap)	do	2,010	150	13.4:1	--	--	--	2,010	150	13.4:1
Perlite	do	1,040	636	1.6:1	W	W	W	1,040	636	1.6:1
Phosphate rock	do	611,000	55,000	11.0:1	W	W	W	611,000	55,000	10.0:1
Potassium salts	do	--	--	--	19,500	2,140	9.1:1	19,500	2,140	9.1:1

See footnotes at end of table.

Table 11.—Material handled per unit of marketable product at surface and underground mines in the United States in 1978, by commodity—Continued

Commodity	Unit of marketable product	Surface			Underground			Total[1]		
		Total material handled[2] (thousand short tons)	Marketable product (units)	Ratio of units of material handled to units of marketable product[3]	Total material handled[2] (thousand short tons)	Marketable product (units)	Ratio of units of material handled to units of marketable product[3]	Total material handled[2] (thousand short tons)	Marketable product (units)	Ratio of units of material handled to units of marketable product[3]
NONMETALS —Continued										
Pumice	do	4,700	4,760	1.0:1	--	--	--	4,700	4,760	1.0:1
Salt	do	3,580	2,870	1.3:1	14,600	14,500	1.0:1	18,200	17,300	1.1:1
Sand and gravel	do	997,000	997,000	1.0:1	--	--	--	997,000	997,000	1.0:1
Sodium carbonate (natural)	do	--	--	--	11,500	6,520	1.8:1	11,500	6,520	1.8:1
Stone:										
Crushed and broken	do	[e]1,120,000	1,030,000	1.1:1	[e]35,900	35,100	1.0:1	[e]1,150,000	1,070,000	1.1:1
Dimension	do	[e]5,830	1,390	4.2:1	W	W	W	[e]5,830	1,390	4.2:1
Talc, soapstone, pyrophyllite	do	2,600	976	2.2:1	366	352	1.0:1	2,970	1,330	1.9:1

[e] Estimate. W Withheld to avoid disclosing company proprietary data.

[1] Data may not add to totals shown because of independent rounding.

[2] Includes material from development and exploration activities.

[3] Material from development and exploration activities is excluded from the ratio calculation.

[4] Less than 1/2 unit.

Table 12.—Mining methods used in open pit mining in 1978, by commodity

(Percent)

Commodity	Total material handled: Preceded by drilling and blasting	Total material handled: Not preceded by drilling and blasting[1]
METALS		
Bauxite	82	18
Copper	94	6
Gold:		
Lode	100	--
Placer	--	100
Iron ore	87	13
Manganiferous ore	52	48
Mercury	10	90
Molybdenum	100	--
Nickel	18	82
Rare-earth metals	100	--
Silver	100	--
Tin	100	--
Titanium, ilmenite	3	97
Tungsten	1	99
Uranium	54	46
Vanadium	50	50
Zinc	100	--
NONMETALS		
Aplite	18	82
Asbestos	99	1
Barite	26	24
Boron minerals	100	--
Clays	--	100
Diatomite	--	100
Emery	100	--
Feldspar	84	16
Fluorspar	73	27
Garnet	84	16
Graphite	--	100
Greensand marl	--	100
Gypsum	64	36
Iron oxide pigments (crude)	--	100
Kyanite	100	--
Lithium minerals	100	--
Magnesite	100	--
Mica (scrap)	45	55
Millstones	92	8
Olivine	59	41
Perlite	38	62
Phosphate rock	4	96
Pumice	4	96
Salt	1	99
Sand and gravel	--	100
Stone:		
Crushed and broken	98	2
Dimension	--	100
Talc, soapstone, pyrophyllite	97	3
Tripoli	99	1
Vermiculite	--	100
Average	53	47

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[1] Includes drilling or cutting without blasting, dredging, mechanical excavation and nonfloat washing, and other surface mining methods.

Table 13.—Exploration and development activity in the United States in 1978, by method

Method	Metals		Nonmetals		Total[1]	
	Feet	Percent of total[2]	Feet	Percent of total[2]	Feet	Percent of total[2]
DEVELOPMENT						
Shaft and winze sinking	11,700	0.3	1,160	6.7	12,900	0.3
Raising	101,000	2.5	3,350	19.3	104,000	2.6
Drifting, crosscutting, or tunneling	801,000	20.0	12,800	74.0	814,000	20.2
Solution mining	3,090,000	77.2	--	--	3,090,000	76.9
Total[1]	4,010,000	100.0	17,300	100.0	4,020,000	100.0
EXPLORATION						
Diamond drilling	1,710,000	7.5	202,000	41.0	1,910,000	8.1
Churn drilling	382,000	1.7	15,600	3.2	397,000	1.7
Rotary drilling	18,900,000	81.9	272,000	55.2	19,100,000	81.4
Percussion drilling	1,260,000	5.5	--	--	1,260,000	5.4
Other drilling	756,000	3.3	3,000	.6	759,000	3.2
Trenching	44,400	.2	250	.1	44,600	.2
Total[1]	23,000,000	100.0	493,000	100.0	23,500,000	100.0
Grand total[1]	27,000,000	XX	510,000	XX	27,500,000	XX

XX Not applicable.

[1] Data may not add to totals shown because of independent rounding.

[2] Based on unrounded footage.

Table 14.—Exploration and development in 1978, by method and selected metals and nonmetals

(Feet)

Commodity	Development					Exploration						
	Shaft and winze sinking	Raising	Drifting, crosscutting, or tunneling	Solution mining	Total[1]	Diamond drilling	Churn drilling	Rotary drilling	Percussion drilling	Other drilling	Trenching	Total[1]
METALS												
Copper	2,890	47,200	124,000	--	174,000	297,000	--	15,100	825	13,800	10,600	337,000
Gold:												
Lode	440	11,900	29,900	--	42,200	205,000	--	51,200	118,000	256	27,200	401,000
Placer	--	--	730	--	730	--	3,750	--	--	2,700	2,740	9,190
Iron ore	--	--	20,200	--	20,200	45,000	--	--	13,400	--	--	58,400
Lead	100	2,940	40,600	--	43,700	195,000	128,000	31,100	2,200	121,000	1,150	478,000
Molybdenum	--	W	W	--	W	173,000	--	8,840	286	1,820	--	184,000
Silver	340	8,600	51,500	--	60,400	26,200	--	15,100	143,000	301	1,510	187,000
Tungsten	363	1,570	11,600	--	13,500	40,500	--	40	12,700	500	--	53,700
Uranium	7,510	21,100	437,000	1,270,000	1,740,000	583,000	247,000	18,700,000	903,000	354,000	1,280	20,800,000
Zinc	96	6,220	57,800	--	64,100	175,000	--	8,890	54,700	4,150	--	243,000
Other[2]	--	993	28,000	1,820,000	1,850,000	15,200	2,650	3,660	9,720	257,000	--	288,000
Total[1]	11,700	101,000	801,000	3,090,000	4,010,000	1,710,000	382,000	18,900,000	1,260,000	756,000	44,400	23,000,000
NONMETALS												
Boron minerals	W	--	W	--	W	--	--	1,500	--	--	--	1,500
Fluorspar	40	1,100	5,800	--	6,940	151,000	--	1,840	--	--	--	153,000
Phosphate rock	--	--	4,950	--	4,950	11,100	--	161,000	--	--	--	172,000
Sodium carbonate (natural)	--	--	--	--	--	1,030	15,600	32,000	--	3,000	--	51,600
Talc, soapstone, pyrophyllite	--	193	338	--	531	--	--	--	--	--	--	--
Other[3]	1,120	2,050	1,750	--	4,930	38,700	--	75,700	--	--	--	114,000
Total[1]	1,160	3,350	12,800	--	17,300	202,000	15,600	272,000	--	3,000	250	493,000
Grand total[1]	12,900	104,000	814,000	3,090,000	4,020,000	1,910,000	397,000	19,100,000	1,260,000	759,000	44,600	23,500,000

W Withheld to avoid disclosing company proprietary data; included with "Other."

[1] Data may not add to totals shown because of independent rounding.

[2] Antimony, bauxite, beryllium, cobalt, manganiferous ore, mercury, nickel, platinum, and rare-earth metals.

[3] Asbestos, barite, clay, perlite, potassium salts, stone (crushed and broken), stone (dimension), and sulfur.

Table 15.—Exploration and development in 1978, by method and State

(Feet)

State	Development					Exploration						
	Shaft and winze sinking	Raising	Drifting, crosscutting, or tunneling	Solution mining	Total[1]	Diamond drilling	Churn drilling	Rotary drilling	Percussion drilling	Other drilling	Trenching	Total[1]
Alaska	--	--	--	--	--	15,000	3,750	--	--	2,710	2,890	24,400
Arizona	790	44,800	90,500	950	137,000	87,000	--	124,000	2,560	13,800	10,800	228,000
California	1,560	2,220	9,620	--	18,500	11,700	225	35,400	10,800	600	225	58,400
Colorado	391	4,400	111,000	--	116,000	267,000	--	1,100,000	221,000	5,180	490	1,600,000
Florida	--	--	--	--	--	--	--	87,200	--	--	--	87,200
Idaho	50	7,650	21,000	--	28,700	34,200	--	22,300	--	--	400	57,900
Michigan	--	--	666	--	666	W	--	--	--	--	--	W
Minnesota	--	--	--	--	--	77,700	--	8,930	1,800	--	500	88,400
Missouri	--	586	51,400	--	52,000	186,000	128,000	26,000	12,100	121,000	--	473,000
Montana	16	290	8,440	--	8,840	23,500	--	663,000	7,250	1	1,080	695,000
Nevada	353	652	9,610	--	10,600	84,500	--	98,800	175,000	2,370	26,900	388,000
New Mexico	3,770	17,400	289,000	--	310,000	44,200	247,000	4,280,000	711,000	350,000	250	5,630,000
New York	--	3,570	18,800	--	22,400	W	--	--	--	--	--	W
Oklahoma	--	--	--	--	--	--	--	5,360	--	--	--	5,360
Oregon	60	109	688	--	857	10,200	--	25,800	270	--	150	36,300
South Dakota	--	W	W	--	W	166,000	--	1,470,000	--	--	--	1,640,000
Tennessee	96	2,360	40,400	--	42,800	163,000	--	57,900	39,800	--	--	260,000
Texas	100	--	800	1,190,000	1,190,000	6,200	--	1,200,000	--	--	--	1,210,000
Utah	4,350	2,740	80,900	870	88,800	386,000	--	2,210,000	68,600	1,210	--	2,670,000
Washington	--	958	1,120	--	2,080	84,400	--	9,450	4,980	--	1,180	100,000
Wisconsin	--	--	--	--	--	4,380	--	1,900	--	1,650	--	7,930
Wyoming	833	4,380	47,000	10,000	62,200	1,620	15,600	7,340,000	--	3,000	--	7,360,000
Undistributed[2]	49	11,000	33,100	1,890,000	1,940,000	254,000	2,420	367,000	8,890	256,000	--	890,000
Total[1]	12,900	104,000	814,000	3,090,000	4,020,000	1,910,000	397,000	19,100,000	1,260,000	759,000	44,600	23,500,000

W Withheld to avoid disclosing company proprietary data; included in "Undistributed."

[1] Data may not add to totals shown because of independent rounding.

[2] Alabama, Arkansas, Georgia, Illinois, Kansas, Kentucky, Maine, Nebraska, North Carolina, Pennsylvania, and Virginia.

Table 16.—Total material (ore and waste) produced by mine development in the United States in 1978, by commodity and State

(Thousand short tons)

	Shaft and winze sinking	Raising	Drifting, crosscutting, or tunneling	Stripping	Total[1]
COMMODITY					
METALS					
Copper	83	1,390	8,290	63,000	72,800
Gold:					
Lode	2	43	143	6,430	6,620
Placer	--	--	2	209	211
Iron ore	--	--	400	81,300	81,700
Lead	1	14	1,760	1	1,780
Silver	1	52	374	1,310	1,740
Tungsten	6	8	105	10	128
Uranium	145	100	1,820	107,000	109,000
Zinc	13	18	1,090	4	1,120
Other[2]	--	13	365	2,280	2,650
Total metals[1]	250	1,640	14,300	262,000	278,000
NONMETALS					
Fluorspar	([3])	8	48	20	76
Phosphate rock	--	--	14	8,240	8,260
Talc, soapstone, pyrophyllite	--	1	1	413	414
Other[4]	5	18	4	3,150	3,170
Total nonmetals[1]	5	26	67	11,800	11,900
Grand total[1]	255	1,666	14,400	274,000	290,000
STATE					
Alabama	--	--	--	W	W
Alaska	--	--	--	167	167
Arizona	23	1,380	7,830	7,990	17,200
Arkansas	--	--	--	W	W
California	5	7	56	3,180	3,240
Colorado	3	23	975	2	1,000
Idaho	([3])	52	162	4,650	4,870
Illinois	W	W	W	W	W
Kentucky	--	--	W	--	W
Michigan	--	--	26	27,200	27,200
Minnesota	--	--	--	54,100	54,100
Missouri	--	4	2,070	--	2,080
Montana	([3])	2	37	39	78
Nevada	6	5	80	10,300	10,400
New Mexico	34	97	1,120	53,700	55,000
New York	--	5	56	279	340
North Carolina	--	--	--	132	132
Oregon	([3])	W	2	([3])	2
Pennsylvania	--	W	W	--	W
South Dakota	--	W	W	--	W
Tennessee	13	11	968	4	995
Texas	1	--	([3])	36,700	36,700
Utah	158	10	709	3,800	4,680
Virginia	--	W	W	W	W
Washington	--	5	5	6,140	6,150
Wyoming	--	17	161	64,500	64,700
Undistributed	5	43	150	880	1,080
Total[1]	255	1,660	14,400	274,000	290,000

W Withheld to avoid disclosing company proprietary data; included with "Undistributed."

[1] Data may not add to totals shown because of independent rounding.

[2] Antimony, bauxite, beryllium, mercury, molybdenum, and rare-earth metals.

[3] Less than 1/2 unit.

[4] Asbestos, boron minerals, garnet, gypsum, iron oxide pigments (crude), potassium salts, pumice, and tripoli.

Table 17.—U.S. industrial consumption of explosives

(Thousand pounds)

Year	Coal mining	Metal mining	Quarrying and nonmetal mining	Total mineral industry	Construction work and other purposes	Total industrial
1974	1,186,614	465,490	551,380	2,203,484	558,806	2,762,290
1975	1,652,251	449,271	493,125	2,594,647	524,380	3,119,027
1976	1,798,873	488,653	493,656	2,781,182	547,347	3,328,529
1977	2,093,312	446,406	522,678	3,062,396	647,354	3,709,750
1978	[1]2,168,630	[1]574,213	[1]604,955	3,347,798	[1] [2]581,391	3,929,189

[1] Some quantities of this use are included with "All other purposes" to avoid disclosing company proprietary data.

[2] Includes some quantities from coal mining, metal mining, quarrying and nonmetal mining, and construction work.

Note: Data for 1977 and 1978 are not comparable to prior years due to change in reporting by the Institute of Makers of Explosives.

Table 18.—U.S. consumption of explosives in the minerals industry

(Thousand pounds)

Year	Coal mining	Metal mining	Quarrying and nonmetal mining	Total
PERMISSIBLE EXPLOSIVES				
1974	38,332	192	1,237	39,761
1975	41,996	241	1,083	43,320
1976	41,123	204	1,090	42,417
1977	46,663	225	694	47,582
1978	38,530	208	618	39,356
OTHER HIGH EXPLOSIVES				
1974	26,301	27,733	99,364	153,398
1975	36,875	25,118	74,796	136,789
1976	34,521	24,265	65,891	124,677
1977	34,407	25,174	63,378	122,959
1978	27,741	25,400	59,974	113,115
WATER GELS AND SLURRIES				
1974	22,204	160,198	75,837	258,239
1975	24,118	181,809	73,872	279,799
1976	30,871	205,429	74,176	310,476
1977	42,406	154,704	75,062	272,172
1978	63,494	234,470	89,322	387,286
AMMONIUM NITRATE: FUEL-MIXED AND UNPROCESSED				
1974	1,099,777	277,367	374,942	1,752,086
1975	1,549,262	242,103	343,374	2,134,739
1976	1,692,358	258,755	352,499	2,303,612
1977	1,969,836	266,303	383,544	2,619,683
1978	2,038,865	314,135	455,041	2,808,041
TOTAL				
1974	1,186,614	465,490	551,380	2,203,484
1975	1,652,251	449,271	493,125	2,594,647
1976	1,798,873	488,653	493,656	2,781,182
1977	2,093,312	446,406	522,678	3,062,396
1978	2,168,630	574,213	604,955	3,347,798

Abrasive Materials

By G. David Baskin[1]

Changes in the 1978 quantity and value of the sales of various natural abrasives, compared with the data for 1977, were of a mixed nature. Output of tripoli-type materials and garnet increased in both tonnage and value. Emery production also increased. But special silica stone product sales decreased in both tonnage and value, and the reported quantity and value of sales of manufactured abrasive material also decreased for 1978.

In 1979 output of tripoli-type materials and special silica stone products decreased in both tonnage and value when compared with the previous year. The tonnage and value of sales of garnet and manufactured abrasives increased when compared to 1978 data.

Table 1.—Salient abrasives statistics in the United States

Kind	1975	1976	1977	1978	1979
Natural abrasives (domestic) sold or used by producers:					
Tripoli (crude) short tons	80,562	124,281	125,661	138,311	[e]127,878
Value thousands	$565	$776	$777	$849	[e]$831
Special silica stone products[1] short tons	2,953	2,696	2,200	[e]2,175	[e]1,944
Value thousands	$1,061	$1,404	$3,226	[e]$2,630	[e]$1,714
Garnet short tons	17,204	24,565	20,022	22,058	23,303
Value thousands	$1,690	[e]$2,740	[e]$2,234	[e]$2,570	[e]$2,831
Emery short tons	3,487	W	W	W	W
Value thousands	W	W	W	W	W
Artificial abrasives[2 3] short tons	528,307	620,328	640,723	550,877	712,733
Value[3] thousands	$141,580	$176,064	$186,654	$172,554	$230,024
Foreign trade (natural and artificial abrasives):					
Exports (value) do	$102,849	$113,199	$121,579	$138,659	$185,587
Reexports (value) do	$28,362	$29,285	$35,363	$41,016	$92,838
Imports for consumption (value) do	$121,863	[r]$157,232	[r]$192,870	$231,720	$270,556

[e]Estimate. [r]Revised. W Withheld to avoid disclosing company proprietary data.

[1]Includes grinding pebbles, grindstones, oilstones, tube-mill liners, and whetstones.

[2]Includes Canadian production of silicon carbide and aluminum oxide and shipments of metallic abrasives by U.S. producers.

[3]Includes U.S. and Canadian production of aluminum-zirconium oxide.

FOREIGN TRADE

The 1978 import values of abrasive materials were 20% more than the 1977 import values, while the 1979 values increased 17% over the previous year. U.S. exports plus reexports, not including metallic abrasives, increased in value 14% in 1978 and 55% in 1979. Net imports, the excess of imports over exports and reexports, not including metallic abrasives, were valued at $57.5 million in 1978 and $0.6 million in 1979.

Industrial diamond imports into the United States in 1978 totaled 22.2 million carats of loose material valued at $87.8 million, a decrease of 2% in quantity and an increase of 11% in value, compared with imports for 1977 and not including diamond dies. In 1979 imports of industrial diamond totaled 25.3 million carats valued at $110.9 million, an increase of 14% in quantity and 26% in value, compared with the previous year. The exports of industrial diamond, loose, totaled 19.1 million carats in 1978, an increase of 8%; their value was $51.2 million, 15% more than the value for 1977. In

1979, exports of industrial diamond totaled 28 million carats, an increase of 47% when compared with the previous year; the value increased 53% to $78.5 million. Reexports of industrial diamond, loose, decreased 15% to 3.3 million carats in 1978, but the value of these reexports increased 15% to $40.2 million. Reexports in 1979 decreased 24% in quantity, compared with 1978 reexports, but the value increased 3% to $41.4 million. In 1978, the diamond content in diamond wheels, exported and reexported, was 718,416 carats, a decrease of 13%; the declared value was $6.0 million, a decrease of 2% from the value declared for 1977. In 1979, diamond content in wheels, exported and reexported, was 589,000 carats, an 18% decrease compared with 1978 quantities; the value increased 10% to $6.6 million. Imports of diamond wheels increased in value in 1978 to $3,558,000 from the 1977 value of $1,882,000. The 1979 value of diamond wheel imports increased 87% to $6,638,000.

The 1978 imports of industrial diamond from Ireland totaled 7.9 million carats, valued at $17.9 million, an increase of 4% in quantity and 1% in value over 1977 imports. Ireland's share of U.S. imports in 1978 was 36% of the total quantity and 20% of the total value. In 1979, imports of industrial diamond from Ireland totaled 9.6 million carats, valued at $20.5 million, an increase of 22% in quantity and 15% in value. Ireland's share of U.S. imports in 1979 was 38% of the total quantity and 18% of the total value (excluding diamond dies). Of the imported bort and powder in 1978, 7.4 million carats were synthetic diamond valued at $14.0 million, and 7.6 million carats were natural diamond valued at $18.9 million. In 1979, synthetic powder and dust totaled 12.9 million carats valued at $23 million while natural bort and powder totaled 5.9 million carats valued at $15.2 million.

Table 2.—U.S. exports of abrasive materials, by kind

(Thousands)

Kind	1977		1978		1979	
	Quantity	Value	Quantity	Value	Quantity	Value
NATURAL ABRASIVES						
Dust and powder of natural and synthetic precious or semiprecious stones, including diamond dust and powder .... carats	17,272	$42,714	18,857	$49,096	27,297	$70,902
Crushing bort, except dust and powder .... do	6	42	--	--	--	--
Industrial diamond .... do	376	1,854	289	2,124	683	7,572
Emery, natural corundum, other natural abrasives, n.e.c .... pounds	38,803	8,147	19,067	890	9,627	1,776
MANUFACTURED ABRASIVES						
Artificial corundum (fused aluminum oxide) .... do	39,361	13,226	32,233	13,671	39,986	19,754
Silicon carbide, crude or in grains .... do	22,441	7,062	24,150	8,080	20,410	9,410
Carbide abrasives, n.e.c .... do	2,074	4,513	558	752	388	987
Other refined abrasives .... do	NA	NA	27,785	6,057	28,206	6,569
Grinding and polishing wheels and stones:						
Diamond .... carats	797	5,900	694	5,759	567	6,401
Pulpstones .... pounds	1,545	966	(1)	(1)	(1)	(1)
Polishing stones, whetstones, oilstones, hones, similar stone .... number	660	1,308	868	1,908	668	1,791
Wheels and stones, n.e.c .... pounds	5,268	14,526	6,763	17,264	6,560	21,083
Abrasive paper and cloth, coated with natural or artificial abrasive materials .... reams	536	17,017	[2]17,223	27,622	[2]18,608	30,864
Coated abrasives, n.e.c .... pounds	NA	4,309	NA	NA	NA	NA
Grit and shot, including wire pellets .... do	NA	NA	33,674	5,434	44,295	8,478
Total	XX	121,579	XX	138,659	XX	185,587

NA Not available. XX Not applicable.

[1] Included in "Wheels and stones, n.e.c."

[2] Quantities for 1978-79 measured in pounds.

Table 3.—U.S. reexports of abrasive materials, by kind

(Thousands)

Kind		1977		1978		1979	
		Quantity	Value	Quantity	Value	Quantity	Value
NATURAL ABRASIVES							
Dust and powder of natural and synthetic precious or semiprecious stones, including diamond dust and powder	carats	464	$1,372	624	$2,006	472	$1,914
Crushing bort, except dust and powder	do	320	1,758	--	--	--	--
Industrial diamond	do	3,132	31,839	2,666	38,205	2,055	39,753
Emery, natural corundum, other natural abrasives, n.e.c	pounds	--	--	97	13	214	49,966
MANUFACTURED ABRASIVES							
Artificial corundum (fused aluminum oxide)	do	--	--	([1])	3	--	--
Silicon carbide, crude or in grains	do	--	--	138	25	--	--
Carbide abrasives, n.e.c	do	5	34	--	--	--	--
Grinding and polishing wheels and stones:							
Diamond	carats	33	235	24	196	22	237
Wheels and stones, n.e.c.[2]	pounds	16	60	36	90	8	147
Abrasive paper and cloth, coated with natural or artificial abrasive materials, including coated abrasives, n.e.c	reams	([1])	5	[3]273	478	[3]348	821
Coated abrasives, n.e.c		NA	60	--	--	--	--
Total		XX	35,363	XX	41,016	XX	92,838

NA Not available. XX Not applicable.

[1] Less than 1/2 unit.

[2] Includes value of hones, whetstones, oilstones, polishing stones, and quantity and value of other abrasive wheels.

[3] Quantities for 1978-79 measured in pounds.

Table 4.—U.S. imports for consumption of abrasive materials (natural and artificial), by kind

(Thousands)

Kind		1977		1978		1979	
		Quantity	Value	Quantity	Value	Quantity	Value
Corundum, crude	short tons	2	$241	([1])	$58	5	$435
Emery, flint, rottenstone, tripoli, crude or crushed	do	9	363	10	611	7	584
Silicon carbide, crude	do	93	25,339	107	30,091	97	30,111
Aluminum oxide, crude	do	180	42,740	195	45,653	211	49,843
Other crude artificial abrasives	do	3	712	2	506	3	795
Abrasives, ground grains, pulverized or refined:							
Rottenstone and tripoli	do	([1])	([1])	([1])	3	4	1
Silicon carbide	do	3	2,731	7	6,807	6	7,480
Aluminum oxide	do	3	1,889	5	3,509	8	5,310
Emery, corundum, flint, garnet, other, including artificial abrasives	do	3	1,752	4	3,104	4	3,781
Papers, cloths, other materials wholly or partly coated with natural or artificial abrasives		([2])	27,952	([2])	38,185	([2])	42,117
Hones, whetstones, oilstones, and polishing stones	number	203	182	831	627	423	518
Abrasive wheels and millstones:							
Burrstones manufactured or bound up into millstones	short tons	([1])	2	([1])	([1])	([1])	3
Solid natural stone wheels	number	8	32	23	19	41	70
Diamond	do	55	1,862	130	3,558	103	4,192
Abrasive wheels bonded with resins	do	1	3,556	[3]2,851	4,796	[3]3,906	6,131
Other		([2])	2,729	([2])	4,460	([2])	5,506
Articles not especially provided for:							
Emery or garnet		([2])	36	([2])	44	([2])	53
Natural corundum or artificial abrasive materials		([2])	345	([2])	522	([2])	770
Other		([2])	685	([2])	800	([2])	1,166
Diamond, natural and synthetic:							
Diamond dies	number	16	580	[r]11	606	11	756
Crushing bort	carats	260	592	177	455	58	219
Other industrial diamond	do	6,263	40,822	5,919	49,018	6,062	65,612
Miners' diamond	do	1,342	6,986	1,276	5,797	1,083	8,067
Dust and powder	do	14,775	30,722	14,811	82,491	18,172	87,016
Total		XX	192,870	XX	231,720	XX	270,556

[r] Revised. XX Not applicable.

[1] Less than 1/2 unit.

[2] Quantity not reported.

[3] Quantities for 1978-79 measured in pounds.

TRIPOLI

Fine-grained, porous silica materials are grouped together under the category tripoli because they have similar properties and end uses. Production of crude tripoli (table 1) increased 10% in quantity and 9% in value in 1978. Processed tripoli sold or used (table 5) decreased 1% in quantity and increased 17% in value. Of the processed tripoli, 66% was used for abrasives in 1978 and 32% was used for fillers, compared with 61% and 37%, respectively, for these uses in 1977.

Tripoli producers in 1978 were Malvern Minerals Co., Garland County, Ark., which produced crude and finished material; Midwestern Minerals Corp., Ottawa County, Okla., which produced crude and finished material; and American Tripoli Co., Div. of The Carborundum Co., which produced crude in Ottawa County, Okla., and finished material in Newton County, Mo. Illinois Minerals Co. and Tammsco, Inc., both in Alexander County, Ill., produced amorphous (microcrystalline) silica. Keystone Filler and Manufacturing Co., in Northumberland County, Pa., mined and processed rottenstone (decomposed fine-grained siliceous limestone or shale).

Prices quoted in Engineering and Mining Journal, December 1978 and December 1979, for tripoli and amorphous silica were as follows:

	1978	1979
Tripoli, paper bags, carload lots, f.o.b., in cents per pound:		
White, Elco, Ill.: Air floated through 200 mesh	2.30	2.55
Rose and cream, Seneca, Mo., and Rogers, Ark.:		
Once ground	2.90	2.90
Double ground	2.90	2.90
Air float	3.15	3.15
Amorphous silica, 50-pound, paper bags, f.o.b., in dollars per ton:		
Elco, Ill:		
Through 200 mesh, 90% to 95%	$35.00-$46.00	$51.00
Through 200 mesh, 96% to 99%	36.00- 47.00	52.00
Through 325 mesh, 90% to 95%	37.00- 48.00	53.00
Through 325 mesh, 96% to 98%	41.00- 52.00	55.50
Through 325 mesh, 98% to 99.4%	39.50- 50.50	57.00
Through 325 mesh, 99.5%	67.50	72.50
Through 400 mesh, 99.9%	91.50	98.50
Below 15 micrometers, 99%	99.50	106.50
Below 10 micrometers, 99%	124.00	131.00

Table 5.—Processed tripoli[1] sold or used by producers in the United States, by use[2]

Use		1974	1975	1976	1977	1978	1979[e]
Abrasives	short tons	50,615	38,815	68,874	70,631	75,574	78,600
Value	thousands	$2,251	$1,518	$2,525	$2,805	$3,709	$3,718
Filler	short tons	33,361	27,630	40,247	42,599	36,505	36,409
Value	thousands	$1,346	$1,205	$1,811	$2,212	$2,220	$2,511
Other	short tons	2,025	1,739	5,000	2,689	[e]2,190	1,000
Value	thousands	$66	$60	$175	$119	[e]$97	$50
Total[3]	short tons	86,000	68,184	114,121	115,919	114,269	116,009
Value[3]	thousands	$3,665	$2,783	$4,511	$5,136	$6,026	$6,279

[e] Estimate.
[1] Includes amorphous silica and Pennsylvania rottenstone.
[2] Partly estimated.
[3] Data may not add to totals shown because of independent rounding.

SPECIAL SILICA STONE PRODUCTS

Special silica stone products produced in 1978-79 included oilstones-whetstones from Arkansas and Indiana, grindstones from Ohio, grinding pebbles from Minnesota and deburring media from Ohio and Wisconsin, and tube-mill liners from Minnesota.

Producers of oilstones-whetstones in Garland County, Ark., were John O. Glassford; Hiram A. Smith, Inc. (closed in 1979); Arkansas Abrasives, Inc.; and Norton Pike Div. of Norton Co. Hindostan Whetstone Co. operated a plant in Lawrence County, Ind., to finish stone obtained from a quarry in Orange County, Ind. Cleveland Quarries Co. produced grindstones at its Amherst quarry, Lorrain County, Ohio. Jasper Stone Co. produced grinding media, rough and rounded, from its quarry in Rock County, Minn.; and Baraboo Quartzite Co. Inc., produced deburring media at its quarry in Sauk County, Wis.

Table 6.—Special silica stone products sold or used in the United States[1]

Year	Quantity (short tons)	Value (thousands)
1974	3,134	$717
1975	2,953	1,061
1976	2,696	1,404
1977	2,200	2,236
1978[e]	2,175	2,630
1979[e]	1,944	1,714

[e]Estimate.

[1]Includes grinding pebbles, grindstones, oilstones, tube-mill liners, and whetstones.

NATURAL SILICATE ABRASIVES

Garnet.—The United States accounts for about 85% of the world's garnet production; the rest comes primarily from India, the U.S.S.R., and Australia. Sales of domestic garnet increased 10% in quantity and 15% in value in 1978, compared with 1977 sales. In 1979, sales increased 6% in quantity and 10% in value, compared with 1978 sales. Four producers were active—two in Idaho, one in New York, and one in Maine. Barton Mines Corp., Warren County, N. Y., sold garnet for use in coated abrasives, glass grinding and polishing, and metal lapping. Emerald Creek Garnet Milling Co. and Idaho Garnet Abrasive Co., both in Benewah County, Idaho, reported their garnet was used in sandblasting, water filtration, as a filler in rubber products, and as an additive in decorative concrete. Industrial Garnet Extractives began garnet production of almandine garnet near Rangeley, Maine. The company expects production to reach 10,000 tons per year, with its main markets in abrasives, water filtration, and production of high-density concrete.

The United States is the largest consumer of garnet, although Japan, the United Kingdom, France, the Federal Republic of Germany, and Italy are also large importers and consumers. With garnet now higher in cost than in previous years, some users are replacing it with synthetic abrasives, but synthetics are not being used in high-quality cabinet work. Some garnet producers expect the product's future growth to be outside the abrasives industry, particularly in water filtration applications.[2]

Table 7.—Abrasive garnet sold or used by producers in the United States

Year	Quantity (short tons)	Value (thousands)
1974	24,684	$2,551
1975	17,204	1,690
1976	24,565	[e]2,740
1977	20,022	[e]2,234
1978	22,058	[e]2,570
1979	23,308	[e]2,831

[e]Estimate.

NATURAL ALUMINA ABRASIVES

Corundum.—No domestic corundum was produced in 1978-79. Requirements for domestic consumption were met by imports, primarily from Nigeria and the Republic of South Africa. Small quantities of corundum were imported from Canada, Switzerland, and India. In 1978, imports totaled 486 tons at a declared value of $57,973. In 1979, imports totaled 4,867 short tons valued at $434,964.

Prices quoted in Engineering and Mining Journal, December 1978 and December 1979, for crystal corundum, per short ton of crude, c.i.f. U.S. ports, were $150 to $160.

Emery.—Two producers of emery were active in 1978: De Luca Emery Mine, Inc., and John Leardi Emery Mine, both near Peekskill in Westchester County, N. Y. Domestic emery was used mostly in aggregates as a nonslip additive for floors, pavements, and stair treads. The minor use for domestic emery was in abrasive materials for coated abrasives and tumbling or deburring media.

World production data available for emery are principally for Greece and Turkey, the primary producers. In 1978, production of emery in Greece was estimated to be 8,960 tons; production in 1979 was approximately 7,200 tons. Turkey's emery production in 1977 was reported as 72,226 tons. No value was computed for production in either country. Emery reserves in Turkey are estimated to total 10 million tons.

Prices quoted for emery in Industrial Minerals, No. 135, December 1978, were as follows, in dollars per metric ton, c.i.f. main European port: Coarse grain, $143 to $152; medium and fine grain, $152 to $171. Prices quoted in Industrial Minerals, No. 147, December 1979, were as follows: Coarse grain, $165 to $176; medium and fine grain, $176 to $198.

Table 8.—Natural corundum: World production by country

(Short tons)

Country[1]	1976	1977	1978[p]	1979[e]
India	[r]526	[r] [e]1,440	1,186	1,200
Kenya	15	--	--	--
South Africa, Republic of	[r]156	152	20	72
U.S.S.R.[e]	8,300	8,800	9,400	9,400
Uruguay	420	464	247	250
Total	[r]9,417	10,856	10,853	10,922

[e]Estimate. [p]Preliminary. [r]Revised.

[1] In addition to the countries listed, Southern Rhodesia presumably continued to produce natural corundum at a significant level (several thousand tons annually), and Argentina may have produced minor quantities of this commodity, but output is not reported and available information is inadequate for formulation of reliable estimates of output level.

INDUSTRIAL DIAMOND

Domestic production of synthetic industrial diamond in 1978 was estimated at 28.7 million carats, an increase of 2.9 million carats over revised estimates for 1977. Production for 1979 was estimated at 42 million carats. Secondary production, or salvage from used diamond tools and from wet and dry diamond-containing wastes, was estimated at 3.0 million carats annually, using data from a consumption canvass conducted by the U.S. Department of Commerce.

The Government stockpile inventory as of December 31, 1979, included 24.0 million carats of crushing bort and 20.0 million carats of stones. Stockpile goals were 15.0 million carats for crushing bort and 5.6 million carats for stones, so excesses are 9.0 million carats and 14.4 million carats, respectively. Bort available for disposal under prior enabling legislation totaled 0.4 million carats. The inventory of small diamond dies was 25,473; the objective was 0; and 25,473 was excess.

The United States is the largest consumer of industrial diamond stones and is totaly dependent on foreign sources. Due to political instability, supplies from Zaire and other areas are in potential danger of disruption. Output of industrial stones is largely dependent on the output of gem diamond, which is limited by economic and other factors not directly related to the demand for industrial stones. World reserves are only marginally sufficient to meet world demand for industrial stones through 2000; therefore, increased use of polycrystalline diamond compacts and other synthetic products will be necessary to be certain that the demand will be met.

Exports and reexports (1979 data in parentheses) of industrial diamond dust and powder, including synthetics, totaled 19.5 (27.8) million carats valued at $51.1 ($72.8) million. Exports and reexports of stones and crushing bort totaled 3.0 (2.7) million carats valued at $40.3 ($47.3) million. The total of exports and reexports of dust and powder, bort, and stones was 22.4 (30.5) million carats valued at $91.4 ($120.1) million.

Domestic exploration for diamonds is underway. More than 90 kimberlite occurrences are known in the Colorado-Wyoming State Line District and the Iron Mountain District of Wyoming. Microdiamonds have been recovered from some of the State-Line diatremes; however, the occurrences have not been thoroughly sampled for a determination of their economic grade. Early-phase exploration is being conducted in Wyoming under an assessment permit granted to Cominco American Inc. by the State of Wyoming and the Rocky Mountain Energy Co.[9]

Since the start of investigations in Wyoming, there has been renewed interest in prospecting other kimberlitic instrusives in Montana, Arizona, and Kentucky. There have been no diamonds reported from these localities.

Table 9.—U.S. imports for consumption of industrial diamond (excluding diamond dies)

(Thousand carats and thousand dollars)

Year	Quantity	Value
1976	17,047	61,102
1977	22,640	79,122
1978	22,190	87,762
1979	25,325	110,934

Table 10.—U.S. imports for consumption of industrial diamond, by country

(Thousand carats and thousand dollars)

Country	Crushing bort (including all types of bort suitable for crushing)						Other industrial diamond (including glazers' and engravers' diamond, unset)					
	1977		1978		1979		1977		1978		1979	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Belgium-Luxembourg	--	--	31	66	--	--	661	2,891	572	2,087	305	2,948
Canada	--	--	--	--	--	--	32	306	36	271	46	617
Congo	--	--	--	--	--	--	104	523	96	687	88	594
Cyprus	--	--	--	--	--	--	2	26	3	50	21	589
Finland	--	--	--	--	--	--	82	100	49	88	2	25
France	--	--	--	--	--	--	11	579	--	--	2	8
Germany, Federal Republic of	--	--	--	--	--	--	1	5	(¹)	12	4	80
Ghana	--	--	--	--	--	--	8	81	23	310	9	212
Greece	--	--	--	--	--	--	--	--	--	--	--	--
Hong Kong	--	--	--	--	--	--	1	14	2	26	4	30
Ireland	15	30	--	--	--	--	17	102	64	210	37	180
Israel	--	--	--	--	--	--	14	240	8	141	3	89
Japan	--	--	--	--	--	--	38	641	26	528	28	1,311
Liberia	--	--	--	--	--	--	2	3	--	--	--	--
Mexico	--	--	--	--	--	--	--	--	5	16	--	--
Netherlands	118	250	(¹)	1	--	--	178	1,650	135	1,808	123	2,146
Sierra Leone	--	--	--	--	--	--	3	196	4	45	(¹)	35
South Africa, Republic of	89	245	146	388	58	219	3,918	24,429	4,383	35,390	4,954	50,746
South-West Africa, Territory of (Namibia)	--	--	--	--	--	--	30	138	2	21	--	--
Spain	--	--	--	--	--	--	--	--	3	8	(¹)	(¹)
Switzerland	22	42	--	--	--	--	1	9	1	20	11	123
Tunisia	--	--	--	--	--	--	--	--	--	--	--	--
U.S.S.R	--	--	--	--	--	--	67	153	34	39	119	129
United Kingdom	15	22	--	--	--	--	1,026	8,013	303	4,521	216	3,160
Upper Volta	--	--	--	--	--	--	--	--	--	--	1	112
Venezuela	--	--	--	--	--	--	9	305	19	699	29	1,543
Other Africa, n.e.c.	--	--	--	--	--	--	84	343	121	1,665	39	576
Zaire	1	3	--	--	--	--	16	29	18	116	8	71
Other	--	--	--	--	--	--	8	47	17	261	16	278
Total	260	592	177	454	58	219	6,268	40,822	5,925	49,018	6,062	65,612

	Miners' diamond						Powder and dust					
	1977		1978		1979		1977		1978		1979	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Belgium-Luxembourg	32	165	18	73	6	31	939	1,586	751	1,144	644	1,109
Canada	31	50	2	28	21	140	110	166	33	63	104	211
Congo	--	--	5	21	--	--	2	4	2	3	1	1
Cyprus	--	--	--	--	--	--	2	12	--	--	55	38
Finland	--	--	--	--	--	--	147	188	387	482	231	339
France	2	24	6	48	--	--	(1)	31	--	--	32	74
Germany, Federal Republic of	4	22	(1)	(1)	2	40	85	76	72	88	172	292
Ghana	1	1	(1)	16	--	--	29	42	3	5	3	24
Greece	--	--	--	--	--	--	--	--	202	319	427	547
Hong Kong	--	--	--	--	--	--	265	257	2	7	--	--
Ireland	39	100	12	42	14	77	7,543	17,455	7,866	17,670	9,597	20,211
Israel	7	39	--	--	--	--	(1)	(1)	51	126	2	4
Japan	277	422	240	329	--	--	591	861	210	276	757	847
Liberia	14	339	(1)	4	--	--	--	--	--	--	--	--
Mexico	--	--	--	--	--	--	16	27	15	27	14	10
Netherlands	(1)	4	(1)	14	(1)	1	27	63	9	25	34	89
Sierra Leone	--	--	(1)	6	--	--	--	--	(1)	(1)	--	--
South Africa, Republic of	92	421	88	473	9	97	2,799	6,961	3,306	9,549	3,527	9,777
South-West Africa, Territory of (Namibia)	--	--	--	--	--	--	--	--	--	--	--	--
Spain	20	41	--	--	--	--	14	32	--	--	--	--
Switzerland	4	26	--	--	--	--	309	459	922	1,110	939	1,188
Tunisia	--	--	--	--	--	--	16	31	--	--	--	--
U.S.S.R	--	--	--	--	--	--	549	684	519	606	1,080	1,145
United Kingdom	4	27	(1)	18	1	3	1,299	1,709	390	808	120	370
Upper Volta	17	108	--	--	--	--	--	--	--	--	--	--
Venezuela	10	458	38	272	3	23	--	--	--	--	--	--
Other Africa, n.e.c.	--	--	--	--	--	--	--	--	--	--	--	--
Zaire	783	4,605	862	4,351	934	7,449	31	95	48	133	321	593
Other	5	139	10	102	43	225	2	3	25	52	111	146
Total[2]	1,342	6,986	1,277	5,797	1,083	8,087	14,775	30,722	14,811	32,498	18,172	37,016

[1] Less than 1/2 unit.

[2] Data may not add to totals shown because of independent rounding.

WORLD REVIEW

Australia.—Diamond exploration in the Kimberley region of Western Australia stirred much excitement during 1978-79. More than 5,500 claims of 120 hectares each were staked by 20 to 30 exploration groups representing 45 to 50 different companies. The most promising results were shown by the Ashton Joint Venture, which is managed by a subsidiary of Conzinc Riotinto of Australia Ltd. Of the 28 kimberlite pipes located, bulk sampling of several yielded more than 14,400 stones. The largest stone found weighed 7.0 carats. Some reports estimate that 50% of the stones were of gem quality. Ashton's Argyle prospect, near Kununurra, is the most likely to become a mine in the near future. Initial samples indicate very high grades of 94 carats per 100 metric tons from the AK.1 kimberlite pipe and 796 carats per 100 metric tons from the alluvial gravel.[4] The claims will not be firmly evaluated until 1980, when more extensive bulk sampling and sample processing is scheduled for completion.[5] [6]

Botswana.—The Jwaneng mine now being developed will reportedly add 6 million carats to the annual diamond production of Botswana by 1985, making that country one of the world's major producers, ranking behind Zaire and the U.S.S.R. Located in the Kalahari Desert, the mine is a joint project of the Botswana Government and De Beers Consolidated Mines Ltd. The Government has negotiated for 77.5% of the profits.[7]

Central African Empire.—Diamond production in 1978 was 284,240 carats; of this amount, 30% were of industrial quality. Total production decreased 4.4% from the 1977 level, and higher prices resulted in a 49% increase in the value of production to $35 million.[8] An Israeli-Iranian-Swiss group obtained a 30,000-square-kilometer concession for diamond exploration and evaluation; but the project dissolved when political instability increased in Iran.[9]

Rhodesia, Southern.—Pilot plant testing of a diamond deposit near Beitbridge is underway. The prospect belongs to De Beers.[10]

South Africa, Republic of.—Diamond production in 1978 is estimated at 7.7 million carats, with 4.1 million carats being of industrial quality. This estimate represents a 1% increase in total production over that of 1977.

De Beers continued plans to increase diamond production from all its mining interests to over 20 million carats by the mid-1980's.[11] In the Republic of South Africa, De Beers' plans include increasing ore production and plant capacity and improving diamond-recovery techniques. Marked improvement in recovery methods in the last 10 years has led to the retreatment of old mine dumps in and around Kimberley. This retreatment is intended to extend the life of the older underground mines, some of which were previously expected to be exhausted before 1990.[12]

The company announced an agreement with the Government for further development of the Premier mine, which has produced over 78 million carats, including 280 stones weighing over 100 carats each. The mine will be extended below a 75-meter-thick barren gabbro sill that cuts across the kimberlite pipe at the 400-meter level. The kimberlite below the sill is expected to yield 14 million tons of ore at a grade of 72 carats per 100 tons.[13] [14]

In northwestern Cape Province, the Koingnaas mine (De Beers) began production planned to total 540,000 carats per year with an apparent operating life of 15 years. The alluvial deposit there will yield small stones averaging 0.25 carat or less. Discovered in 1962, the deposit could not be economically mined until recently, when diamond prices increased sharply and market conditions improved for small stones.[15]

The Finsch mine (De Beers) also in Cape Province, is scheduled to increase its ore production approximately 40% to 420,000 tons per month. In addition, plans are to increase capacity at the treatment plant and to substantially improve diamond recovery. On the basis of a 6-day working week, it is anticipated that the new capacity will allow for an increase in the mine's present diamond production of 2.4 million carats per year. Production is expected to increase by about 1 million carats per year.[16] Industrial diamond recoveries presently amount to about 85% of the mine's total diamond production.

An expansion program has begun that is projected to increase production capacity of De Beers-Sibeka (Sibeka is a Belgian company) synthetic industrial diamond to more than 60 million carats annually. This production would equal 60% of the synthetic diamond in the 1978 market. The three-phase program, which includes plants in the Republic of South Africa, Ireland, and Sweden, is scheduled for completion in 1980.[17]

U.S.S.R.—Diamond exports, estimated at

$750 million in 1978, are the fourth largest source of hard currency for the U.S.S.R.[18] An estimated 10.6 million carats were mined in 1978; 80% of this amount was of industrial quality.

Zaire.—Total diamond production in 1978 was 11,250,000 carats; 95% to 97% of this total was of industrial quality. Production was unchanged from that of the previous year.

TECHNOLOGY

An improved method for bonding synthetic diamond-cutting elements to drill bits has been developed by Sandia Laboratories, Albuquerque, N. Mex. The diffusion-bonding technique involves attaching the cutters to a tungsten-carbide stud or directly to a bit body. Polycrystalline compact cutters and studs are coated with nickel, locked together, and placed in a thin-walled steel can filled with a pressure-transfer medium (graphite). The evacuated, sealed can is placed in an autoclave and subjected to pressures of 30,000 pounds per square inch (psi) at 1,202° F for 4 hours. Under these conditions, the metallization layers flow and the surface impurities diffuse into the nickel, creating a uniform, high-quality weld. The resulting bonds have shear strengths of 60,000 to 80,000 psi. Field tests are planned to test the bonds using igneous formations and shale. The work is funded by the U.S. Department of Energy's Division of Fossil Fuels Extraction.[19]

Lamage, Ltd., of Canada, has developed a new design for an exploratory diamond-drilling core bit using synthetic diamonds. The new bit, made of numerous small segments spaced to allow flushing of cuttings, performs well in both hard and soft formations with penetration rates of 11 to 36 centimeters per minute. Advantages claimed for the new design include: Lower cost per foot and lower investment; fewer bit types required; lower pressures used in drilling, resulting in less hole deviation, less wear on bearings and equipment, and lower fuel consumption; and the advantage of the bit staying down the hole longer, resulting in fewer round trips for the drill string.[20]

A flexible, throw-away diamond abrasive pad invented by D. H. Prowse and Co. Ltd., is designed to expedite and lower the cost of finishing contoured surfaces, notably in the ophthalmic industry's lens production operations. The new electroplated diamond product can reduce the time required for prefinishing and polishing by at least 50% and can outlast its conventional abrasive counterpart by 1,000 times.[21]

Wheel Trueing Tool Co. of Columbia, S. C., has developed a process for impregnating mining tool bits with industrial diamonds in a way that reduces diamond costs but requires technical exactitude in metallurgy. The company can use synthetic diamonds for impregnation in powdered metal; in some cases, synthetics perform better and are less expensive than natural diamonds.[22]

Diamond SA of Lausanne, Switzerland, has developed a new technique for the economic manufacture of profiled polycrystalline diamond cutting tools. With the new technique it is possible to produce straight edges, radii, angles, and combinations of these to suit the desired tool geometry. The polycrystalline diamond material shows significant advantages over conventional tooling materials especially when machining aluminum; magnesium and its alloys; nonferrous metals containing silicon; nonferrous metals such as copper, brass, bronze, and zinc and its alloys; ceramics; porcelain; reinforced and nonreinforced plastics; rubber; and, for certain applications, gold, platinum, and silver. Monocrystalline diamond tools are still required for turning and milling operations designed to produce a gloss or polished finish.[23]

Abstracts were published relative to the properties of diamond, hard materials, machines, and patents on a monthly basis in the Industrial Diamond Review. Each issue, from January to December 1978 and 1979, contains 11 to 25 pages of abstracts and patent information.

Table 11.—Diamond (natural): World production, by type and country[1]

(Thousand carats)

Country	1976			1977			1978[p]			1979[e]		
	Gem	Industrial	Total	Gem	Industrial	Total	Gem	Industrial	Total	Gem	Industrial	Total
Africa:												
Angola	255	85	340	265	88	353	525	175	700	562	188	750
Botswana	358	2,026	2,384	404	2,287	2,691	418	2,367	2,785	500	2,840	3,340
Central African Empire	172	114	286	178	119	297	199	85	284	210	90	300
Ghana	228	2,055	2,283	230	[r]1,717	1,947	142	1,281	1,423	150	1,350	1,500
Guinea[e]	25	55	80	25	55	80	25	55	80	27	58	85
Ivory Coast	[r]22	[r]38	60	[r]7	[r]11	[r]18	--	10	10	--	5	5
Lesotho	1	4	5	7	35	42	13	53	66	14	56	70
Liberia[2]	[r]163	[r]162	[r]325	168	168	336	128	180	308	130	180	310
Sierra Leone	[r]433	[r]650	[r]1,083	423	538	961	283	424	707	285	425	710
South Africa, Republic of:												
Premier mine	458	1,375	1,833	502	1,508	2,010	496	1,487	1,983	495	1,485	1,980
Other De Beers properties[3]	2,549	2,086	4,635	2,796	2,287	5,083	2,903	2,376	5,279	2,900	2,300	5,200
Other	333	222	555	[r]330	[r]220	[r]550	279	186	465	275	185	460
Total	3,340	3,683	7,023	[r]3,628	[r]4,015	[r]7,643	3,678	4,049	7,727	3,670	3,970	7,640
South-West Africa, Territory of, (Namibia)	1,609	85	1,694	1,901	100	2,001	1,803	95	1,898	1,850	100	1,950
Tanzania	219	219	[3]438	[r]204	[r]204	[r] [3]408	146	147	[3]293	145	145	290
Zaire	591	11,230	11,821	561	10,652	11,213	562	10,688	11,250	560	10,600	11,160
Other areas:												
Brazil	38	38	76	[r]33	[r]32	[r]65	43	43	86	45	45	90
Guyana	6	8	14	7	10	17	7	10	17	7	10	17
India	17	3	20	[r]15	3	[r]18	14	2	16	14	2	16
Indonesia[e]	3	12	15	3	12	15	3	12	15	3	12	15
U.S.S.R.[e]	2,000	7,900	9,900	2,100	8,200	10,300	2,150	8,400	10,550	2,200	8,500	10,700
Venezuela	[r]195	[r]654	[r]849	[r]204	[r]483	[r]687	278	460	738	285	465	750
World total	[r]9,675	[r]29,021	[r]38,696	10,358	28,724	39,082	10,417	28,536	38,953	10,657	29,041	39,698

[e]Estimate. [p]Preliminary. [r]Revised.

[1] Total diamond output (gem plus industrial) for each country is actually reported except where indicated by a footnote to be estimated. In contrast, the detailed separate production data for gem diamond and industrial diamond are Bureau of Mines estimates in the case of every country except Central African Empire (1976-78), Liberia (1976-78), Sierra Leone (1977-78), and Venezuela (1978) for which source publications give details on grade as well as totals. The estimated distribution of total output between gem and industrial diamond is conjectural in the case of a number of countries, based on unofficial information of varying degrees of reliability.

[2] Total exports.

[3] All company output from the Republic of South Africa, except for that credited to the Premier mine; excludes De Beers Group output from Botswana, Lesotho, and the Territory of South-West Africa (Namibia).

ARTIFICIAL ABRASIVES

Five firms produced crude fused aluminum oxide in the United States and Canada in 1978. Operators with plants in both countries were: The Carborundum Co., Div. of Kennecott Copper Corp.; Norton Co.; and General Abrasive Co., Div. of Dresser Industries, Inc. The Exolon Co. and Unicorn Abrasives of Canada, Ltd., Div. of Fusion du Saguenay (Simonds Canada Abrasive Co. Ltd.), operated plants in Canada. The reported 1978 production of white, high-purity material was 27,955 tons and production of regular material was 114,153 tons. Of the combined output of white and regular material, 10% was used for nonabrasive applications, principally in the manufacture of refractories. Stocks reported totaled 19,552 tons as of December 31, 1978. The estimated 1979 production of white, high-purity material was 45,560 tons; production of regular material was 179,391 tons. Approximately 8% of total production was used for nonabrasive applications. The estimated production was 95% of the rated capacity of U.S. and Canadian plants. Stocks reported totaled 15,323 tons as of December 31, 1979.

One firm, General Abrasive Co., Div. of Dresser Industries Inc., produced fused alumina-zirconia abrasive in the United States and in Canada; and three firms, Carborundum, Norton, and Exolon, operated plants in Canada. All production was reportedly used for abrasive applications. In 1978, output was 88% of the capacity of the furnaces that were used for production of fused alumina-zirconia. Stocks reported totaled 1,436 tons as of December 31, 1978. In 1979, estimated output was 95% of capacity. Stocks reported totaled 4,283 tons as of December 31, 1979.

Six firms in the United States and Canada produced silicon carbide in 1978. In 1979, a seventh company, ESK Inc., began production in Hennepin, Ill. The Carborundum Co., operating plants in both countries, decided to close its Jacksboro, Tenn., plant. The main reason for the closure was the escalating cost of energy in the area.[34] In Canada, plants were operated by Electro-Refractories & Abrasives Canada, Ltd.; Exolon; Norton; and General Abrasive Co. These companies produced crude for abrasive uses and for refractory and other nonabrasive uses. Satellite Alloy Corp. operated in the United States and produced crude for nonabrasive applications. Production reported in 1978 by the six firms was 78% of capacity, and 27% of the output was reportedly used for abrasive applications. Nonabrasive use accounted for the remaining 73% of output. Most of the nonabrasive uses of crude were in refractory and metallurgical applications. Stocks totaled 7,255 tons as of December 31, 1978, according to reports. In 1979, production reported was 95% of capacity. Of the total output, approximately 35% was used in abrasive applications. Stocks totaled 5,857 tons as of December 31, 1979.

In the Stockpile Report to the Congress by the General Services Administration, the inventory of crude fused aluminum oxide in calendar year 1979 was 249,864 tons; 73,901 tons was uncommitted excess. The stock of aluminum oxide grain decreased slightly to 50,786 tons; the goal was 75,000 tons. The stock of silicon carbide crude was 80,537 tons, and the goal was unchanged at 306,628 tons.

Metallic abrasives were produced by 12 firms in the United States in 1979. Steel shot and grit comprised 90% of the total quantity sold or used; chilled iron shot and grit, 7%; and annealed iron shot and grit, 2%. Pennsylvania supplied 24% of the total sold or used. Other large suppliers operated in Ohio, Michigan, Indiana, Virginia, Alabama, Connecticut, and New York. Three companies recycled metallic abrasives: Copperweld Steel Co. of Glassport, Pa.; Industeel Corp. of Pittsburgh, Pa.; and Kohler Co. of Sheboygan, Wis.

TECHNOLOGY

A fused abrasive grain developed by Corning Glass Works of Corning, N. Y., has less tendency to chip and lower rates of attritious wear than conventional fused alumina-zirconia abrasives. It consists of crystalline phases of corundum and zirconia with an average crystallite size smaller than 300 micrometers. Fused raw material is formed into grain of appropriate particle sizes for use in grinding wheels and coated abrasive products.[25]

Cutting tool inserts are being manufactured from hot-pressed silicon nitride. In this new application the high strength, resistance to thermal shock, and good high-temperature properties of the material allow positive-rake cutting geometry and higher cutting speeds on hard, abrasive metals.[26]

Table 12.—Producers of metallic abrasives in 1978-79

Company	Location	Product shot and/or grit
Abbott Ball Co	West Hartford, Conn	Cut wire.
Abrasive Materials, Inc	Hillsdale, Mich	Steel and stainless steel cut wire.
Abrasive Metals Co	Pittsburgh, Pa	Chilled iron and annealed iron.
The Carborundum Co., Pangborn Div.	Butler, Pa	Steel.
Cleveland Metal Abrasive Co.	Birmingham, Ala	Do.
Do	Howell, Mich.[1]	Chilled iron.
Do	Springville, N.Y	Do.
Do	Toledo, Ohio	Steel.
Durasteel Co	Mt. Pleasant, Pa.	Do.
Ervin Industries, Inc.	Adrian, Mich	Chilled iron and steel.
Globe Steel Abrasive Co.	Mansfield, Ohio	Steel.
Metal Blast, Inc.	Cleveland, Ohio	Chilled and annealed iron.
National Metal Abrasive Co	do.	Steel.
Steel Abrasives, Inc	Hamilton, Ohio	Chilled and annealed iron.
Wheelabrator-Frye Inc	Mishawaka, Ind	Steel.
Do	Bedford County, Va.	Do.

[1] Plant closed in 1979.

Table 13.—Crude artificial abrasives produced in the United States and Canada

(Thousand short tons and thousand dollars)

Kind	1974	1975	1976	1977	1978	1979
Silicon carbide[1]	162	134	159	192	182	[e]196
Value	$33,872	$31,842	$45,958	$53,814	$51,271	[e]$62,702
Aluminum oxide (abrasive grade)[1]	241	141	191	185	142	[e]225
Value	$40,906	$28,868	$43,356	$48,819	$46,633	[e]$67,511
Aluminum-zirconium oxide	25	17	20	20	23	28
Value	$9,839	$8,506	$11,388	$11,281	$14,668	$14,893
Metallic abrasives[2]	351	236	250	243	204	264
Value	$91,061	$72,364	$75,372	$72,740	$59,982	$84,918
Total	780	528	620	640	551	[e]713
Value	$175,678	$141,580	$176,064	$186,654	$172,554	[e]$230,024

[e] Estimate.

[1] Figures include material used for refractories and other nonabrasive purposes.

[2] Shipments for U.S. plants only.

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[1] Physical scientist, Section of Nonmetallic Minerals.

[2] Harben, P. Abrasives—Taking the Rough With the Smooth. Ind. Miner., No. 134, November 1978, pp. 49-73.

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[23] Industrial Diamond Review. Syndite Profile Tools. December 1979, p. 442.

[24] Industrial Minerals. Company News. No, 147, December 1979, p. 66.

[25] Page 184 of work cited in footnote 21.

[26] Materials Engineering. Tooling Up With Silicon Nitride. V. 90, No. 4, October 1979, pp. 51-53.

Table 14.—Production, shipments, and annual capacities of metallic abrasives in the United States, by product

Year and product	Manufactured		Sold or used		Annual capacity[1] (short tons)
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	
1977:					
Chilled iron shot and grit	22,533	$4,481	28,934	$6,238	86,600
Annealed iron shot and grit	7,372	1,244	8,308	1,940	25,600
Steel shot and grit	191,316	49,215	205,612	64,282	305,100
Other[2]	27	140	78	280	--
Total	221,248	55,080	242,932	72,740	XX
1978:					
Chilled iron shot and grit	20,504	4,243	24,273	5,665	62,500
Annealed iron shot and grit	7,248	1,368	8,016	1,867	41,210
Steel shot and grit	243,252	70,968	170,576	50,669	314,700
Other[2]	635	874	836	1,680	495
Total	271,639	77,453	203,701	59,881	XX
1979:					
Chilled iron shot and grit	18,766	4,870	19,299	3,172	[e]50,000
Annealed iron shot and grit	6,170	2,197	6,309	2,698	[e]25,000
Steel shot and grit[e]	232,475	65,631	238,190	78,329	295,400
Other[2]	290	582	337	719	1,200
Total	257,701	73,280	264,135	84,918	XX

[e] Estimate. XX Not applicable.

[1] Total quantity of the various types of metallic abrasives that a plant could have produced during the year, working three 8-hour shifts per day, 7 days per week, allowing for usual interruptions, and assuming adequate fuel, labor, and transportation.

[2] Includes cut wire shot.

[illegible]

Table 12.—Crude artificial abrasives produced in the United States and Canada

[illegible]

Aluminum

By Horace F. Kurtz[1] and Christine M. Moore[2]

Primary aluminum production in the United States established a record high level of over 5 million short tons in 1979. An increasing trend in annual production from the low level of the 1970's, set in 1975, continued through 1978 and 1979, despite plant shutdowns resulting from electric power shortages. Annual demand, as measured by net shipments of aluminum ingot and mill products to domestic industry, was 6.8 million tons in 1978 and in 1979, near the 6.9-million-ton record level of 1973. Net imports of aluminum, including scrap, fell from 560,000 tons in 1978 to 67,000 tons in 1979 as total exports rose to a record high level.

World production of aluminum increased steadily from 15 million tons in 1977 to nearly 16 million tons in 1979. Notable changes during the 2-year period, in addition to the recovery of U.S. production, included significant production from new facilities in Venezuela and the shutting down of capacity in Japan. Announcements of plans for new production capacity indicated that major expansion will occur in Australia in the first half of the 1980's.

Table 1.—Salient aluminum statistics

(Thousand short tons and thousand dollars)

	1975	1976	1977	1978	1979
United States:					
Primary production	3,879	4,251	4,539	4,804	5,023
Value	$2,976,427	$3,785,397	$4,683,949	$5,191,064	$6,130,302
Price: Ingot, average cents per pound	39.8	44.6	51.6	54.6	59.4
Secondary recovery	980	1,155	1,271	1,323	1,401
Exports (crude and semicrude)	440	484	411	520	778
Imports for consumption (crude and semicrude)	550	749	836	1,080	840
Aluminum industry shipments[1]	4,555	5,956	[r]6,119	6,830	6,805
Consumption, apparent	3,907	[r]5,083	[r]5,492	6,045	5,895
World: Production	13,387	[r]13,787	[r]15,093	15,510	15,979

[r]Revised.

[1]To domestic industry.

Legislation and Government Programs.—The Tokyo Round of trade negotiations was completed in 1979, resulting in new tariff agreements among the developed nations of the world. The agreements, which affected aluminum tariffs, placed most nations in a "most-favored-nation" status and provided for declining rates to be phased in, or staged, over an 8-year period. The initial rates, beginning January 1, 1980, included the following: Unwrought aluminum (in coils), 3.1% ad valorem; unwrought aluminum (other than aluminum silicon alloys), 0.8 cent per pound; wrought aluminum (bars, plates, sheets, strip), 3% ad valorem.

Government stockpiles of aluminum remained at less than 2,000 tons throughout 1978 and 1979.

DOMESTIC PRODUCTION

Primary.—Domestic primary aluminum production totaled 4,803,762 short tons in 1978 and 5,023,098 tons in 1979. Production capacity increased from 5,193,000 tons at yearend 1977 to 5,282,000 tons at yearend 1979.

A strike by coal miners in the first quarter of 1978 forced several primary aluminum producers to reduce production temporarily. Noranda Aluminum Inc. shut down its 140,000-ton-per-year smelter at New Madrid, Mo., for approximately 1 month. Eastalco Aluminum Co. cut production by 30% at its Frederick, Md., primary aluminum smelter. Anaconda Aluminum Co. cut production at its Sebree, Ky., plant by about 10%. The Aluminum Co. of America (Alcoa) shut down half of one potline at its Evansville, Ind., smelter until April 1979.

Alcoa stopped primary aluminum production at its Point Comfort, Tex., smelter in April 1978 due to the high cost of energy. Production was resumed in May 1979 because of increased demand for aluminum, and by yearend four of seven potlines were in operation.

Reynolds Metals Co. resumed production at its Corpus Christi, Tex., primary aluminum smelter in May 1979 and reached full capacity production at the facility by yearend.

Anaconda Aluminum Co. began production of primary aluminum in June 1979 in a new 60,000-ton-per-year potline at its Sebree, Ky., smelter. The expansion increased the capacity of the facility to 180,000 tons per year.

The Bonneville Power Administration (BPA) began a 25% curtailment of interruptible power on July 1, 1979, affecting three of the six primary aluminum producing companies in the Pacific Northwest. By yearend, announced cutbacks totaled 167,300 tons per year of capacity. Alcoa shut down 34,500 tons per year of capacity at Vancouver, Wash., and 42,000 tons per year at Wenatchee, Wash. Reynolds reduced production at Troutdale, Oreg., and Longview, Wash., by a total of 40,800 tons per year, and Kaiser Aluminum & Chemical Corp. slowed production by a total of 50,000 tons per year at its Mead, Wash., and Tacoma, Wash., smelters. In addition to the reduced operating rates resulting from the power shortage in the Northwest, the Anaconda smelter at Columbia Falls, Mont., operated at only 86% of capacity, as a modernization program was underway during the last half of 1979.

In 1978, the South Carolina Department of Health and Environmental Control approved permits for the construction of a 197,000-ton-per-year primary aluminum smelter to be built by Alumax, Inc., in Berkley County. Startup of the $400 million facility was scheduled for 1980. Alumax stopped construction of a third potline at the Eastalco smelter when Potomac Edison Power Co. informed the company that it would be unable to provide the power required by the expansion.

Martin Marietta Corp. announced plans to expand its Goldendale, Wash., primary aluminum smelter by 65,000 tons per year to 177,000 tons per year. The project, estimated to cost $125 million, was scheduled for completion in 1981.

Kaiser Aluminum announced plans to install 10 prototype reduction cells at two primary aluminum smelters in an effort to improve energy efficiency and lower emissions. Construction of the cells was scheduled to start by yearend 1979, and production startup was planned for mid-1981. Should the cells prove efficient, further modernization of the Chalmette, La., and Tacoma, Wash., primary aluminum smelters would be considered.

Alcoa reportedly encountered corrosion problems at its Palestine, Tex., experimental aluminum production facility. Production at the 15,000-ton-per-year facility was cut by half until the problems could be resolved.

The Tennessee Valley Authority increased the rates charged for power supplied to industrial customers to 23 mills per kilowatt-hour, effective July 2, 1978. Primary aluminum producers affected by the price increase included Alcoa, Consolidated Aluminum Co., Revere Copper & Brass, Inc., and Reynolds. BPA also announced a price increase for power supplied to industrial customers, including six primary aluminum producers. The average cost per kilowatt-hour for aluminum production in the Pacific Northwest was expected to increase from about 3.2 mills per kilowatt-hour to 8.7 mills per kilowatt-hour, effective December 1979.

Secondary.—Reynolds began expansion

of its Bellwood, Va., aluminum can and scrap recycling facilities in 1978. Alcoa and Reynolds set up facilities in Michigan to collect aluminum and steel cans which would be recycled at plants in Indiana and Tennessee.

Wabash Alloys Inc. began expansion of its secondary smelting capacity in 1979 to 150,000 tons per year. Howmet Aluminum Co. built a 37,500-ton-per-year secondary smelter at Rockwall, Tex., which was scheduled to begin operations during 1980. Secondary smelters operated by Kripke-Tuschman Industries Inc. at Toledo, Ohio, and by Huron Steel Corp. at Trenton, Miss., were shut down in 1978.

Table 2.—Consumption of and recovery from purchased new and old aluminum scrap[1]

(Short tons)

Class	Consumption	Calculated recovery	
		Aluminum	Metallic
1978			
Secondary smelters	882,697	700,827	755,153
Primary producers	437,360	375,763	402,407
Fabricators	155,035	135,296	144,664
Foundries	101,850	87,442	93,902
Chemical producers	39,572	21,578	22,078
Total	1,616,514	1,320,908	1,418,204
Estimated full industry coverage	1,911,000	1,554,000	1,673,000
1979			
Secondary smelters	922,159	736,277	793,458
Primary producers	442,262	378,734	405,661
Fabricators	190,354	167,187	178,669
Foundries	104,323	89,394	96,203
Chemical producers	45,933	27,664	28,171
Total	1,705,031	1,399,256	1,502,162
Estimated full industry coverage	2,020,000	1,654,000	1,777,000

[1] Excludes recovery from other than aluminum-base scrap.

Table 3.—Aluminum recovered from purchased scrap processed in the United States, by kind of scrap and form of recovery

(Short tons)

Kind of scrap	1977	1978	1979	Form of recovery	1977	1978	1979
New scrap:				Unalloyed	1,743	216	2,176
Aluminum-base	[1]857,651	[2]871,633	[3]920,994	Aluminum alloys	1,218,100	1,271,537	1,342,013
Copper-base	[r]102	57	95	In brass and bronze	[r]108	116	184
Zinc-base	260	243	253	In zinc-base alloys	1,389	974	1,017
Magnesium-base	249	312	327	In magnesium alloys	567	646	616
				Dissipative forms[4]	49,337	49,155	55,067
Total	[r]858,262	872,245	921,669	Total	[r]1,271,244	1,322,644	1,401,073
Old scrap:							
Aluminum-base	[1]411,488	[2]449,275	[3]478,262				
Copper-base	47	59	89				
Zinc-base	1,129	731	764				
Magnesium-base	318	334	289				
Total	412,982	450,399	479,404				
Grand total	[r]1,271,244	1,322,644	1,401,073				

[r] Revised.

[1] Aluminum alloys recovered from aluminum-base scrap in 1977, including all constituents, were 915,205 tons from new scrap and 447,687 tons from old scrap and sweated pig, a total of 1,362,892 tons.

[2] Aluminum alloys recovered from aluminum-base scrap in 1978, including all constituents, were 930,285 tons from new scrap and 487,919 tons from old scrap and sweated pig, a total of 1,418,204 tons.

[3] Aluminum alloys recovered from aluminum-base scrap in 1979, including all constituents, were 982,899 tons from new scrap and 519,263 tons from old scrap and sweated pig, a total of 1,502,162 tons.

[4] Includes recovery in deoxidizing ingot assuming 85% aluminum content in such ingot.

Table 4.—Stocks, receipts, and consumption of purchased new and old aluminum scrap and sweated pig in the United States in 1978[1]

(Short tons)

Class of consumer and type of scrap	Stocks Jan. 1	Net receipts[2]	Consumption	Stocks Dec. 31
Secondary smelters:				
New scrap:				
Solids and clippings	22,163	296,490	296,661	21,992
Borings and turnings	W	W	W	W
Foil	433	1,962	2,083	312
Dross and skimmings	8,875	117,402	115,582	10,695
Other[3]	9,811	169,880	170,213	9,478
Total new scrap	41,282	585,734	584,539	42,477
Old scrap:				
Castings, sheet, clippings	11,283	151,657	145,770	17,170
Aluminum cans	2,833	27,350	27,197	2,986
Other[4]	4,135	31,773	33,592	2,316
Total old scrap	18,251	210,780	206,559	22,472
Sweated pig	18,811	85,919	91,599	13,131
Total all classes	78,344	882,433	882,697	78,080
Primary producers, foundries, fabricators, chemical plants:				
New scrap:				
Solids and clippings	51,863	371,805	396,477	27,191
Borings and turnings	W	W	W	W
Foil	1,546	4,909	5,390	1,065
Dross and skimmings	521	27,678	27,682	517
Other[3]	3,203	57,537	58,339	2,401
Total new scrap	57,133	461,929	487,888	31,174
Old scrap:				
Castings, sheet, clippings	1,351	55,531	55,480	1,402
Aluminum cans	11,084	142,403	139,970	13,517
Other[4]	2,332	26,693	26,773	2,252
Total old scrap	14,767	224,627	222,223	17,171
Sweated pig	828	24,140	23,706	1,262
Total all classes	72,728	710,696	733,817	49,607
Total of all scrap consumed:				
New scrap:				
Solids and clippings	74,026	668,295	693,138	49,183
Borings and turnings	9,909	166,794	167,145	9,558
Foil	1,979	6,871	7,473	1,377
Dross and skimmings	9,396	145,080	143,264	11,212
Other	3,105	60,623	61,407	2,321
Total new scrap	98,415	1,047,663	1,072,427	73,651
Old scrap:				
Castings, sheet, clippings	12,634	207,188	201,250	18,572
Aluminum-copper radiators	3,161	16,479	17,886	1,754
Aluminum cans	13,917	169,753	167,167	16,503
Other	3,306	41,987	42,479	2,814
Total old scrap	33,018	435,407	428,782	39,643
Sweated pig	19,639	110,059	115,305	14,393
Total all classes	151,072	1,593,129	1,616,514	127,687

W Withheld to avoid disclosing company proprietary data.

[1] Includes imported scrap. According to the reporting companies 10% of total receipts of aluminum-base scrap, or 160,388 short tons, was received on toll arrangements.

[2] Includes inventory adjustment.

[3] Includes data on borings and turnings.

[4] Includes data on aluminum-copper radiators.

Table 5.—Stocks, receipts, and consumption of purchased new and old aluminum scrap and sweated pig in the United States in 1979[1]

(Short tons)

Class of consumer and type of scrap	Stocks Jan. 1	Net receipts[2]	Consumption	Stocks Dec. 31
Secondary smelters:				
New scrap:				
Solids and clippings	21,992	302,049	307,474	16,567
Borings and turnings	9,286	173,104	173,071	9,319
Foil	W	W	W	W
Dross and skimmings	10,695	100,016	104,524	6,187
Other[3]	504	20,356	20,303	557
Total new scrap	42,477	595,525	605,372	32,630
Old scrap:				
Castings, sheet, clippings	17,170	180,153	182,363	14,960
Aluminum cans	2,986	27,979	28,771	2,194
Other[4]	2,316	33,058	32,940	2,434
Total old scrap	22,472	241,190	244,074	19,588
Sweated pig	13,131	67,786	72,713	8,204
Total all classes	78,080	904,501	922,159	60,422
Primary producers, foundries, fabricators, chemical plants:				
New scrap:				
Solids and clippings	27,191	412,064	421,647	17,608
Borings and turnings	272	17,259	17,248	283
Foil	W	W	W	W
Dross and skimmings	517	28,319	28,158	678
Other[3]	3,194	53,156	51,926	4,424
Total new scrap	31,174	510,798	518,979	22,993
Old scrap:				
Castings, sheet, clippings	1,402	58,535	58,239	1,698
Aluminum cans	13,517	151,882	151,191	14,208
Other[4]	2,252	27,974	27,734	2,492
Total old scrap	17,171	238,391	237,164	18,398
Sweated pig	1,262	27,648	26,729	2,181
Total all classes	49,607	776,837	782,872	43,572
Total of all scrap consumed:				
New scrap:				
Solids and clippings	49,183	714,113	729,121	34,175
Borings and turnings	9,558	190,363	190,319	9,602
Foil	1,377	8,450	8,125	1,702
Dross and skimmings	11,212	128,335	132,682	6,865
Other	2,321	65,062	64,104	3,279
Total new scrap	73,651	1,106,323	1,124,351	55,623
Old scrap:				
Castings, sheet, clippings	18,572	238,688	240,602	16,658
Aluminum-copper radiators	1,754	19,158	19,169	1,743
Aluminum cans	16,503	179,861	179,962	16,402
Other	2,814	41,874	41,505	3,183
Total old scrap	39,643	479,581	481,238	37,986
Sweated pig	14,393	95,434	99,442	10,385
Total all classes	127,687	1,681,338	1,705,031	103,994

W Withheld to avoid disclosing company proprietary data.

[1] Includes imported scrap. According to the reporting companies 8.45% of total receipts of aluminum-base scrap, or 142,122 short tons, was received on toll arrangements.

[2] Includes inventory adjustment.

[3] Includes data on foil.

[4] Includes data on aluminum-copper radiators.

Table 6.—Production and shipments of secondary aluminum alloys by independent smelters

(Short tons)

	1977		1978		1979	
	Production	Net shipments	Production	Net shipments	Production	Net shipments
Die-cast alloys:						
13% Si, 360, etc. (0.6% Cu, maximum)	82,325	83,580	108,646	107,787	98,867	100,267
380 and variations	413,364	416,661	424,296	426,745	453,555	452,575
Sand and permanent mold:						
95/5 Al-Si, 356, etc. (0.6% Cu, maximum)	24,487	24,306	28,143	28,777	26,818	26,854
No. 12 and variations	W	W	W	W	W	W
No. 319 and variations	48,674	49,761	54,305	53,401	56,099	55,731
F-132 alloy and variations	15,771	15,778	17,877	18,007	21,317	21,238
Al-Mg alloys	1,355	1,249	1,993	1,765	1,854	2,213
Al-Zn alloys	18,328	17,671	12,223	12,889	7,929	7,742
Al-Si alloys (0.6% to 2.0% Cu)	4,548	4,748	8,005	7,843	6,161	6,152
Al-Cu alloys (1.5% Si, maximum)	3,050	3,315	2,199	2,093	3,216	3,213
Al-Si-Cu-Ni alloys	3,573	3,673	3,336	3,442	3,794	3,850
Other	3,684	3,616	4,451	4,513	8,392	8,473
Wrought alloys: Extrusion billets	87,979	87,500	91,727	90,893	101,982	101,446
Destructive and other uses: Steel deoxidation:						
Grades 1, 2, 3, and 4	[r]29,776	[r]30,659	37,237	37,066	39,095	39,611
Miscellaneous:						
Pure (97.0% Al)	W	W	216	592	2,176	2,172
Aluminum-base hardeners	2,548	2,574	2,563	2,314	3,422	3,631
Other[1]	[r]26,871	[r]27,174	23,044	22,429	10,386	10,626
Total	766,333	772,265	820,261	820,556	845,063	845,794
Less consumption of materials other than scrap:						
Primary aluminum	26,403	--	32,076	--	38,613	--
Primary silicon	40,239	--	49,868	--	48,834	--
Other	4,712	--	4,000	--	4,338	--
Net metallic recovery from aluminum scrap and sweated pig consumed in production of secondary aluminum ingot[2]	694,979	--	734,317	--	753,278	--

[r]Revised. W Withheld to avoid disclosing company proprietary data; 1977-78 included in "Miscellaneous," and "Other categories;" 1979 included in "Other Sand and Permanent Mold."

[1] Includes data withheld (Other die cast alloys, No. 12 and variations (1977 and 1978 only), Pure (97.0% Al) (1977 only), and Other miscellaneous).

[2] No allowance made for melt-loss of primary aluminum and alloying ingredients.

CONSUMPTION

The apparent consumption of aluminum in end products such as automobiles, cans, and residential siding, as estimated by the Bureau of Mines and shown in table 7, reached a record high level of over 6 million tons in 1978 and declined slightly in 1979.

Net shipments of aluminum ingot and mill products to domestic manufacturers of end products rose to about 6.8 million tons in 1978 and leveled off in 1979. Shipments to all major industry segments in 1978 increased over those of 1977. In 1979, containers and packaging replaced building and construction as the largest market for aluminum. Shipments to the containers and packaging industry and the electrical industry showed the greatest growth during the 2-year period.

An analysis of energy savings in the use of aluminum in automobiles was published.[3] The estimated average consumption of aluminum in automobiles rose from 87 pounds per unit in 1976 models to 118 pounds per unit in 1979 models. Usage in 1985 models has been forecast at 200 pounds per unit.

The use of aluminum by the aerospace industry was estimated at 125,000 tons in 1978.[4] Consumption of aluminum by this industry, largely commercial and military air transport, was expected to reach 250,000 tons in 1980.

Table 7.—Apparent aluminum supply and consumption in the United States

(Thousand short tons)

	1975	1976	1977	1978	1979
Primary production	3,879	4,251	4,539	4,804	5,023
Change in stocks:[1]					
Aluminum industry	-421	^{r}+149	^{r}-3	+106	+191
Government	+2	+9	--	--	--
Imports	550	749	836	1,080	840
Secondary recovery:[2]					
New scrap	899	1,062	1,074	1,098	1,163
Old scrap	337	409	531	575	614
Total supply	5,246	^{r}6,629	^{r}6,977	7,663	7,831
Less total exports	440	484	411	520	773
Apparent aluminum supply available for domestic manufacturing	4,806	^{r}6,145	^{r}6,566	7,143	7,058
Apparent consumption [3]	3,907	^{r}5,083	^{r}5,492	6,045	5,895

^{r}Revised.

[1] Positive figure indicates a decrease in stocks; negative figure indicates an increase in stocks.

[2] Metallic recovery from purchased, tolled, or imported new and old aluminum scrap expanded for full industry coverage.

[3] Apparent aluminum supply available for domestic manufacturing less recovery from purchased new scrap (a measure of consumption in manufactured end products).

Table 8.—Distribution of end use shipments of aluminum products

Industry	1977		1978		1979^{p}	
	Quantity (thousand short tons)	Percent of total	Quantity (thousand short tons)	Percent of total	Quantity (thousand short tons)	Percent of total
Building and construction	^{r}1,499	23.1	1,604	22.3	1,526	20.9
Transportation	^{r}1,439	^{r}22.2	1,544	21.4	1,512	20.7
Containers and packaging	1,389	^{r}21.5	1,571	21.8	1,612	22.0
Electrical	^{r}662	^{r}10.2	736	10.2	779	10.6
Consumer durables	^{r}526	^{r}8.1	575	8.0	504	6.9
Machinery and equipment	^{r}455	^{r}7.0	494	6.9	467	6.4
Other markets	^{r}292	4.5	306	4.2	405	5.5
Statistical adjustment	^{r}-143	^{r}-2.2				
Total to domestic users	^{r}6,119	^{r}94.4	6,830	94.8	6,805	93.0
Exports	363	^{r}5.6	374	5.2	512	7.0
Total	^{r}6,482	100.0	7,204	100.0	7,317	100.0

^{p}Preliminary. ^{r}Revised.

Source: The Aluminum Association, Inc.

Table 9.—Net shipments of aluminum wrought[1] and cast products by producers

(Short tons)

	1977	1978	1979
Wrought products:			
Sheet, plate, foil	[r]3,423,024	3,642,651	3,602,560
Rolled and continuous-cast rod and bar; wire	[r]467,431	582,831	618,080
Extruded rod, bar, pipe, tube, shapes; drawn and welded tubing and rolled structural shapes	1,197,998	1,311,354	1,263,261
Powder, flake, paste	60,561	67,970	62,782
Forgings (including impacts)	60,644	68,203	73,770
Total	[r]5,209,658	5,673,009	5,620,453
Castings:			
Sand	113,373	120,767	143,026
Permanent mold	219,633	218,171	221,644
Die	652,292	642,185	613,395
Other	19,178	21,337	17,591
Total	1,004,476	1,002,460	995,656
Grand total	[r]6,214,134	6,675,469	6,616,109

[r] Revised.

[1] Net shipments derived by subtracting the sum of producers' domestic receipts of each mill shape from the domestic industry's gross shipment of that shape.

Source: U.S. Department of Commerce.

Table 10.—Distribution of wrought products

(Percent)

	1977	1978	1979
Sheet, plate, foil:			
Non-heat-treatable	53.8	52.1	51.3
Heat-treatable	4.1	4.5	4.9
Foil	7.7	7.7	7.9
Rolled and continuous-cast rod and bar; wire:			
Rod, bar, wire	2.3	3.1	3.5
Cable and insulated wire	6.7	7.1	7.5
Extruded products:			
Rod and bar	.8	1.0	.9
Pipe and tubing	1.8	1.6	1.4
Shapes[1]	18.3	18.6	18.6
Tubing:			
Drawn	1.0	.9	.9
Welded, non-heat-treatable[2]	1.1	1.0	.7
Powder, flake, paste	1.2	1.2	1.1
Forgings (including impacts)	1.2	1.2	1.3
Total	100.0	100.0	100.0

[1] Includes a small amount of rolled structural shapes.

[2] Includes a small amount of heat-treatable welded tube.

Source: U.S. Department of Commerce.

STOCKS

Metal inventories held at reduction and other processing plants as reported by the Bureau of Industrial Economics, U.S. Department of Commerce, declined from 2,853,178 tons (revised) at yearend 1977 to 2,746,978 tons at yearend 1978 and to 2,555,920 tons at yearend 1979.

PRICES

The price of 99.5% pure aluminum ingot as quoted by the American Metal Market was increased from 53.0 cents per pound at the beginning of 1978 to a range of 55.5 to 57.5 cents per pound at yearend. By yearend 1979, the price had been increased to a range of 66.0 to 66.5 cents per pound.

The range of prices of smelters' secondary aluminum ingot as quoted in the American Metal Market in 1978 was increased from 50.0 to 64.0 cents per pound at the beginning of the year to 58.0 to 70.5 cents per pound at yearend. By yearend 1979, the range had been increased to 71.0 to 83.0 cents per pound. The price of aluminum-base scrap ranged from 27.5 to 36.0 cents per pound at the beginning of 1978 and 29.5 to 35.5 cents per pound by yearend. At yearend 1979, the price of aluminum-base scrap ranged from 37.0 to 49.0 cents per pound.

FOREIGN TRADE

Exports of crude and semicrude aluminum increased in 1978 and 1979, with exports of scrap accounting for the largest increases in both years. Canada, Japan, and Mexico remained major recipients of the shipments, but Venezuela, Brazil, and the Republic of Korea increased their imports from the United States during the 2-year period.

Imports of crude and semicrude aluminum, including scrap, increased 29% in 1978, but declined to about the 1977 level in 1979. The largest change in both years was in receipts of metal and alloys from Canada.

Table 11.—U.S. exports of aluminum, by class

Class	1978		1979	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Crude and semicrude:				
Ingots, slabs, crude	126,617	$134,483	200,650	$264,296
Scrap	194,508	140,756	307,080	290,316
Plates, sheets, bars, etc	186,895	321,557	248,027	501,850
Castings and forgings	NA	88,445	7,404	35,671
Semifabricated forms, n.e.c	11,861	37,352	10,224	38,236
Total	519,881	722,593	773,385	1,130,369
Manufactures:				
Foil and leaf	62,435	30,148	25,171	45,419
Powders and flakes	7,292	11,147	7,182	12,979
Wire and cable	51,593	73,842	11,248	24,137
Total	121,320	115,137	43,601	82,535
Grand total	641,201	837,730	816,986	1,212,904

NA Not available.

Table 12.—U.S. exports of aluminum, by class and country

Country	1978						1979					
	Ingots, slabs, crude		Plates, sheets, bars, etc.[1]		Scrap		Ingots, slabs, crude		Plates, sheets, bars, etc.[1]		Scrap	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Australia	17	$35	1,649	$3,679	--	--	1,467	$2,227	2,184	$5,711	1,504	$2,095
Austria	7	25	1,766	2,394	81	$55	--	--	765	1,084	36	34
Belgium-Luxembourg	11	44	806	2,285	744	576	692	978	1,128	3,257	8,414	7,479
Brazil	4,037	3,662	4,091	8,975	13,694	9,941	3,160	4,240	5,589	12,441	18,162	14,394
Canada	12,148	12,048	87,280	197,714	16,589	10,528	20,928	30,499	127,466	264,666	14,509	11,762
Chile	965	1,063	80	458	273	318	408	509	117	431	324	407
Colombia	85	145	599	1,344	44	46	90	179	500	1,161	--	--
Costa Rica	227	265	982	1,804	--	--	451	525	1,117	1,635	--	--
Denmark	2	8	3,794	6,563	--	--	129	235	3,285	6,255	6	6
El Salvador	813	960	60	320	9	68	1,509	2,021	1,270	1,808	--	--
Finland	560	611	272	533	42	29	58	66	320	627	2,047	1,601
France	6,156	6,034	2,465	7,015	242	121	7,004	9,509	6,566	14,786	1,262	1,109
Germany, Federal Republic of	5,096	5,476	5,825	15,490	13,740	8,420	3,476	5,251	6,866	17,886	28,070	22,831
Greece	(2)	1	1,362	2,944	20	79	--	--	1,041	2,178	--	--
Indonesia	1,057	1,073	683	1,868	--	--	472	559	443	1,148	--	--
Iran	59	106	7,413	7,900	--	--	1	2	191	502	--	--
Ireland	1	3	1,863	4,166	15	18	6	26	1,084	2,789	7	26
Israel	311	617	2,744	6,984	36	71	335	760	2,887	7,818	55	66
Italy	151	297	3,264	10,476	2,815	1,858	1,294	2,419	7,946	23,306	9,599	8,171
Jamaica	81	146	625	1,241	43	37	19	53	334	686	21	21
Japan	47,237	48,233	3,645	13,380	127,466	97,646	99,376	118,824	8,329	22,443	173,808	178,207
Korea, Republic of	9,377	9,440	719	2,555	1,314	993	11,206	14,469	963	2,815	3,375	3,258
Malaysia	1,979	2,482	663	867	--	--	1,217	974	1,598	2,640	--	--
Mexico	21,674	24,073	23,239	45,754	3,643	2,964	24,316	33,209	27,748	50,634	12,370	13,381
Morocco	--	--	1	2	--	--	--	--	1,411	2,713	--	--
Netherlands	199	498	3,665	9,208	1,571	967	3,957	6,948	6,886	16,002	9,683	8,488
Pakistan	29	35	34	66	562	288	695	1,074	336	568	765	541
Panama	854	911	294	1,002	--	--	1,411	1,659	242	763	--	--
Peru	24	31	43	276	200	210	271	406	39	180	603	950
Philippines	2,240	2,522	166	1,583	52	55	2,511	2,977	619	1,437	187	267
Saudi Arabia	101	188	2,739	9,045	--	--	228	731	2,273	6,565	--	--

Singapore	511	597	1,493	3,610	19	23	1,760	2,105	676	1,671	386	488
South Africa, Republic of	8	20	2,721	5,298	224	149	96	198	2,142	4,392	165	171
Spain	21	51	1,368	2,444	1,830	729	39	29	1,930	4,340	6,409	3,318
Sweden	1,779	1,912	198	972	559	418	331	407	285	1,260	3,449	2,982
Switzerland	1,070	1,812	177	714	15	10	814	1,018	464	1,734	165	146
Taiwan	3,185	3,384	988	3,791	7,228	2,855	3,882	5,188	968	3,718	7,992	4,459
Thailand	1,214	1,295	353	902	70	22	1,262	1,725	571	1,489	4	3
United Kingdom	571	972	16,383	30,965	649	458	2,756	4,755	23,846	47,136	2,412	2,146
Venezuela	355	461	6,795	13,220	13	20	91	153	7,121	14,348	33	43
Other	1,803	2,946	5,497	17,535	704	787	2,832	7,394	6,209	19,845	1,058	1,466
Total[3]	126,617	134,483	198,756	447,354	194,508	140,756	200,650	264,296	265,655	575,757	307,080	290,316

[1] Includes plates, sheets, bars, extrusions, forgings, and unclassified semifabricated forms.
[2] Less than 1/2 unit.
[3] Data may not add to totals shown because of independent rounding.

Table 13.—U.S. imports for consumption of aluminum, by class

Class	1978		1979	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Crude and semicrude:				
Metals and alloys, crude	757,092	$745,255	570,634	$645,769
Circles and disks	10,236	16,813	10,765	19,929
Plates, sheets, etc., n.e.c	207,502	296,492	168,710	289,671
Rods and bars	11,641	16,345	20,867	31,020
Pipes, tubes, etc	1,129	2,058	674	2,690
Scrap	92,153	68,056	68,316	59,430
Total	1,079,753	1,145,019	839,966	1,048,509
Manufactures:				
Foil	60,725	33,964	8,963	34,906
Leaf	([1])	130	([1])	112
Flakes and powders	318	520	1,680	3,224
Wire	1,345	2,650	1,563	3,077
Total	62,388	37,284	12,206	41,319
Grand total	1,142,141	1,182,303	852,172	1,089,828

[1] 1978—Aluminum leaf not over 30.25 square inches in area, 1,793,020 leaves, and aluminum leaf over 30.25 square inches in area, 59,135,928 square inches; 1979—aluminum leaf not over 30.25 square inches in area, 1,164,331 leaves, and aluminum leaf over 30.25 square inches in area, 152,758,208 square inches.

Table 14.—U.S. imports for consumption of aluminum, by class and country

Country	1978						1979					
	Metals and alloys, crude		Plates, sheets, bars, etc.[1]		Scrap		Metals and alloys, crude		Plates, sheets, bars, etc.[1]		Scrap	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Argentina	--	--	708	$955	--	--	--	--	1,473	$2,128	--	--
Australia	--	--	886	1,266	--	--	(2)	$(2)	6,090	10,577	10	$9
Austria	--	--	3,795	5,989	18	$4	--	--	3,549	6,507	--	--
Bahrain	1,101	$1,128	--	--	--	--	--	--	--	--	--	--
Belgium-Luxembourg	52	67	48,852	65,229	250	186	--	--	30,798	50,505	350	513
Canada	523,045	515,317	15,573	24,679	45,064	31,224	372,480	407,948	16,744	30,347	58,955	46,394
France	6,843	6,511	22,346	31,398	810	557	--	--	15,549	29,270	--	--
Germany, Federal Republic of	5,612	6,396	14,616	24,372	1,122	848	2,964	4,841	4,372	10,085	1	(2)
Ghana	88,161	98,173	--	--	--	--	109,808	134,835	--	--	12	9
Greece	--	--	523	729	--	--	--	--	933	1,525	--	--
Hong Kong	--	--	1,692	2,460	--	--	--	--	2,403	3,921	1	1
Israel	--	--	828	1,782	805	509	--	--	1,255	3,256	163	166
Italy	3,667	3,698	10,676	14,328	--	--	2,432	2,729	9,273	15,381	--	--
Japan	124	176	62,168	92,753	4	1	46	233	45,960	83,604	--	--
Mexico	43	22	1,498	2,390	1,756	716	254	198	797	1,481	1,505	998
Netherlands	--	--	3,100	7,525	49	26	50	87	3,670	11,728	71	212
Norway	55,362	43,691	8,864	11,266	--	--	44,056	52,811	12,782	19,527	--	--
Romania	655	633	6,545	7,226	--	--	113	108	7,557	8,879	--	--
South Africa, Republic of	11,530	11,317	14	28	--	--	361	362	--	--	--	--
Spain	19	15	1,423	2,177	--	--	551	747	3,593	5,560	--	--
Surinam	17,177	15,546	--	--	--	--	13,501	13,783	--	--	--	--
Sweden	13,294	12,011	2,384	3,286	--	--	3,331	3,701	1,464	2,500	--	--
Switzerland	2,001	3,440	1,183	1,686	551	447	117	291	728	1,654	147	209
Taiwan	--	--	967	1,214	--	--	--	--	992	1,358	--	--
U.S.S.R	17	100	--	--	36,734	29,881	11	80	--	--	9,886	8,830
United Kingdom	14,871	14,995	2,192	3,897	2,499	1,918	7,635	9,501	7,362	11,185	26	9
Venezuela	10,083	8,904	4,568	4,859	1,086	720	12,928	13,518	12,099	14,277	1,053	1,251
Yugoslavia	3,325	3,016	14,836	20,350	20	15	--	--	10,687	17,509	--	--
Other	110	99	274	361	1,385	1,005	1	1	286	547	1,136	829
Total[3]	757,092	745,255	230,508	381,708	92,158	68,056	570,634	645,769	201,016	343,310	68,316	59,430

[1] Includes circles, disks, bars, plates, sheets, pipes, etc.

[2] Less than 1/2 unit.

[3] Data may not add to totals shown because of independent rounding.

WORLD REVIEW

World primary aluminum capacity increased in 1978 and 1979. New primary aluminum smelters began production in Dubai, Spain, and Venezuela during that period. During 1979, significant expansion plans by several companies in Australia were announced.

Stocks of primary aluminum held by members of the International Primary Aluminum Institute (IPAI), which represent the bulk of inventories held outside the centrally controlled economies, decreased 10% during 1978 and an additional 15% during 1979.

The London Metal Exchange began trading aluminum futures on October 2, 1978. Aluminum trading contracts were based on 25-metric-ton lots of minimum 99.5% pure aluminum ingot.

Algeria.—A 10-year contract was signed for Jamaica to supply 165,000 tons per year of alumina to a planned 135,000-ton-per-year primary aluminum smelter to be built at M'sila.

Argentina.—The hydroelectric facilities at Futaleufu were completed in 1978. Aluminio Argentino (ALUAR) announced plans to increase primary aluminum production at its Puerto Madryn smelter from 55,000 tons per year to 154,000 tons per year, the rated capacity of the plant, by 1980.

Australia.—Alcoa of Australia Pty. Ltd. announced plans to add a third potline at its Point Henry primary aluminum smelter. The $110 million expansion, scheduled to begin production in late 1980, would increase production capacity to 182,000 tons per year. Alcoa also announced plans to build a 132,000-ton-per-year smelter at Portland, Victoria. The $350 million facility was scheduled to start up in 1983.

Comalco Pty. Ltd. announced plans to begin construction in 1979 of a two-potline, 225,000-ton-per-year primary aluminum smelter at Gladstone, Queensland. The $678 million facility would use Sumitomo Aluminum Smelting Co. technology. Startup was scheduled for mid-1982.

Alumax, Inc., undertook a feasibility study for a $605 million primary aluminum smelter to be built at Farley, New South Wales. Production at the 260,000-ton-per-year facility was scheduled for 1984. Participation in the project by Broken Hill Proprietary was announced.

Alcan Australia Ltd. announced plans to expand its Kurri Kurri alumina reduction facility to 99,000 tons per year by 1981 and to 150,000 tons per year by late 1982. Alcan Queensland Pty. Ltd. undertook a feasibility study for a 110,000-ton-per-year smelter to be built near Gladstone. Startup of the facility, to be expanded later to 275,000 tons per year, was scheduled for 1983.

Aluminium Pechiney Australia Pty. Ltd. was formed to build a 120,000-ton-per-year primary aluminum smelter at Hunter Valley, New South Wales. The $570 million facility was scheduled to begin production in 1983 and would be expanded to 240,000 tons per year by 1985. Gove Alumina Ltd. and the Australian Mutual Providence Society planned to participate in the project.

Bahrain.—Plans were announced by Aluminium Bahrain Co. (Alba) to expand its primary aluminum smelter capacity to 187,000 tons per year. Construction was scheduled to start in 1979 with completion scheduled for 1981. The Government of Saudi Arabia purchased a 20% share in Alba from the Government of Bahrain. Other shareholders in the company included the Government of Bahrain (58%), Kaiser Aluminum and Chemical Co. (17%), and Breton Investments (5%).

Brazil.—A group of 11 French and 4 Brazilian firms signed contracts to supply equipment, materials, and services for the Tucurui hydroelectric project. The power facilities, estimated to cost $2.5 billion, would supply the 350,000-ton-per-year Albras primary aluminum smelter.

Vale do Sul Aluminio S. A. (Valesul) began construction of an 88,000-ton-per-year primary aluminum smelter at Santa Cruz, Rio de Janeiro. Cia. International de Engenharia was awarded the contract to construct the $370 million facility, which was scheduled to come onstream in 1981. Valesul is owned 60% by Cia Vale do Rio Doce, 35% by Shell Brasil S. A., and 5% by Reynolds International Inc.

Companhia Mineira de Aluminio began construction of a third potline at its Poços de Caldas, Minas Gerais, primary aluminum smelter. Startup in 1979 increased the facility's capacity to 99,000 tons per year.

Alcan Aluminio do Brasil, S. A., announced plans to expand its Aratu primary aluminum smelter by 33,000 tons per year. The additional capacity, which will use the Sumitomo Söderberg process, was scheduled for completion in 1981.

Aluminio de Nordeste (Alune) was established to build an 110,000-ton-per-year primary aluminum smelter near Recife. The $400 million facility would use alumina from the Alunorte alumina refinery near Belém upon its completion.

Cameroon.—Cie. Camerounaise de l'Aluminium, owned 58% by Pechiney Ugine Kuhlmann and 42% by the Government of Cameroon, announced plans to increase the capacity of the Edea primary aluminum smelter from 46,000 tons per year to 88,000 tons per year by 1981.

Canada.—Alcan Aluminium Ltd. began construction of a 189,000-ton-per-year primary aluminum smelter at Ville de La Baie, Quebec. The first of three potlines was scheduled to come onstream in 1980. Power for the $200 million plant would be supplied by hydroelectric facilities owned by Alcan.

Expiration of a labor contract forced the closing of three Alcan Quebec smelters in June 1979, and the company subsequently declared force majeure on ingot supply commitments. A new, 3-year contract was signed September 4, 1979.

Alcan announced plans to double the generating capacity of its Kemano, British Columbia, hydroelectric facility.

China, mainland.—Nippon Light Metal Co., C. Itoh & Co., and Toko Bussan Co. Ltd. reportedly signed a contract to build an 88,000-ton-per-year primary aluminum smelter in Kishu Province. Startup was scheduled for 1981.

The Government of China was also planning a 660,000-ton-per-year primary aluminum smelter in Kwangsi Province. The facility would use power from the proposed Lungnan hydroelectric power station.

Germany, Federal Republic of.—Alcan Aluminium-Werke G.m.b.H. purchased the 48,000-ton-per-year Gebruder Giulini primary aluminum smelter at Ludwigshafen for $12.1 million.

Ghana.—A power failure in May 1978 cut production by 80% at the Volta Aluminium Co. Ltd. primary aluminum smelter at Tema. The facility resumed full capacity production in November 1979.

Guinea.—A feasibility study was undertaken for an integrated aluminum smelting complex by Swiss Aluminium Ltd. for the Governments of Guinea, Egypt, Saudi Arabia, Kuwait, Iraq, Libya, and the United Arab Emirates. The project, to be located in Guinea, would include development of bauxite deposits, an alumina refinery, and a primary aluminum smelter.

Hungary.—Plans were under consideration for a 110,000-ton-per-year primary aluminum smelter to be built near Inota.

India.—Bharat Aluminium Co. completed the third and fourth 25,000-ton-per-year potlines at its smelter at Korba, Madhya Pradesh. Production was delayed due to power shortages.

The Government of Uttar Pradesh approved plans of Hindustan Aluminium Corp., Inc., to build a captive power plant to insure power supplies to its primary aluminum smelter at Renukoot.

Kaiser Aluminum & Chemical Corp. sold its 27% equity in Hindustan Aluminium Corp., Inc. to the Government of India.

Pechiney Ugine Kuhlmann and Bharat Aluminium Co. signed a letter of intent to undertake a feasibility study for a 660,000- to 880,000-ton-per-year alumina refinery and a 176,000-ton-per-year primary aluminum smelter to be built in Orissa.

Indonesia.—Construction was begun on the 248,000-ton-per-year P. T. Inalum primary aluminum smelter at Asahan during 1979. Production startup was scheduled for 1982.

Japan.—The Industrial Structural Council of the Ministry of International Trade and Industry recommended the freezing of about 585,000 tons per year of aluminum production capacity until 1983. At the end of that period, a decision would be made either to permanently scrap the facilities or to restart the potlines. In line with this program, companies froze 455,000 tons per year of capacity and scrapped an additional 155,000 tons per year of production facilities.

Gove Alumina Pty. Ltd. agreed to supply Sumikei Aluminum Industries Ltd. 660,000 tons of alumina over a 12-year period starting in 1980 for use at its Sakata primary aluminum smelter.

Malaysia.—Pechiney Ugine Kuhlmann and Hyundai Heavy Industries undertook a feasibility study for a primary aluminum smelter at Labuan, Sabah. Reynolds Metals Co. began a feasibility study for a 110,000-ton-per-year primary aluminum smelter to be built as a joint venture with the Sarawak State Government. Reportedly, the $720 million facility would initially be based on power derived from natural gas from the Bintulu gasfield but would eventually use hydroelectric power.

Mexico.—The Mexican Government decided to postpone indefinitely the 165,000-ton-per-year primary aluminum smelter planned as a joint venture with the Jamaican Government. Alumina was to have been supplied by Jamaica.

Norway.—A/S Ardal og Sunndal Verk announced plans to expand its primary aluminum smelter at Hoyanger from 33,000 tons per year to 48,000 tons per year by yearend 1981. Alcan Aluminium Ltd. sold its remaining 25% interest in Ardal og Sunndal Verk to the Government of Norway for $70 million.

Norsk Hydro A/S announced plans to increase the production capacity of its smelter at Karmoy from 121,000 tons per year to 173,000 tons per year. Plans for a new smelter at Glomfjord were canceled due to high energy costs.

Philippines.—Reynolds Metals Co., the Aluminium Co. of the Philippines, and the Government of the Philippines began discussions on the construction of a primary aluminum smelter on one of the southern islands of the archipelago.

Poland.—The Government of Poland announced plans to expand the Huta Aluminiowa primary aluminum smelter from 66,000 tons per year to 154,000 tons per year over a 5-year period.

Spain.—Construction of the 198,000-ton-per-year primary aluminum smelter at San Cipriano by Aluminio Espanol S. A. was completed, and production started January 9, 1979.

Sweden.—Alcan Aluminium Ltd. sold its 21% share in Granges Essem AB to Granges AB. Granges Aluminium AB, a wholly owned subsidiary of Granges Essem AB, operates a 93,000-ton-per-year aluminum smelter at Sundsvall.

Trinidad/Tobago.—Southwire Co. undertook a feasibility study for a 198,000-ton-per-year primary aluminum smelter in Trinidad.

United Arab Emirates.—Production at the 149,000-ton-per-year primary aluminum smelter in Dubai commenced in November 1979. Dubai Aluminium Co. was owned 80% by the Government of Dubai and 20% by Alusmelter Holdings, a company formed by Alcan (U. K.) Ltd. and Southwire Co.

United Kingdom.—Reynolds Metals Co. sold its interest in British Aluminium Co. for $86 million. Tube Investments Ltd. increased its share in British Aluminium to 58%. British Aluminium Co. announced plans to modernize its primary aluminum smelter at Lochaber. Capacity at the facility would be increased to 41,000 tons per year by the program, which was scheduled for completion in 1981.

Venezuela.—Venezolano de Aluminio (Venalum), a joint venture of the Government agency Corporation Venezolano de Guayana and six Japanese firms, began production at the 310,000-ton-per-year primary aluminum smelter at Ciudad Guyana. Full capacity production was scheduled for 1981.

Yugoslavia.—Construction of a third potline at the Sibenik primary aluminum smelter was started in 1978. The expansion will increase production capacity by 50,000 tons per year to 132,000 tons per year. Planning for a new primary aluminum smelter in Mostar continued.

Zaire.—Swiss Aluminium Ltd. (Alusuisse) and the Government of Zaire signed a cooperation agreement to build a 165,000-ton-per-year primary aluminum smelter near Banana. Alusuisse would design the $555 million facility, which was scheduled to start up in the mid-1980's. Alumina would be supplied by the Nabalco Pty. Ltd. alumina refinery at Gove, Australia.

Table 15.—Aluminum: World production,[1] by country

(Thousand short tons)

Continent and country	1976	1977	1978[p]	1979[e]
North America:				
Canada	698	1,073	1,156	[2]935
Mexico	47	47	47	[2]48
United States	4,251	4,539	4,804	[2]5,023
South America:				
Argentina	48	55	59	100
Brazil	158	184	205	[2]264
Surinam	[r]51	[3]53	63	[2]68
Venezuela	51	48	83	[2]230
Europe:				
Austria	98	101	101	[2]102
Czechoslovakia	[r]40	40	40	40
France	424	441	431	[2]436
German Democratic Republic[e]	65	72	72	70
Germany, Federal Republic of	768	818	815	[2]818
Greece	148	143	159	[2]155
Hungary	78	79	79	80
Iceland	72	82	81	[2]80
Italy	228	287	295	[2]297
Netherlands	282	266	288	[2]282
Norway	[r]681	693	705	[2]742
Poland[4]	114	115	110	[2]106
Romania[5]	228	230	235	240
Spain	232	233	234	[2]286
Sweden	91	91	87	[2]90
Switzerland	86	88	88	[2]91
U.S.S.R.[e]	1,760	1,810	1,840	1,900
United Kingdom	369	386	382	[2]396
Yugoslavia	218	218	216	[2]209
Africa:				
Cameroon	64	61	46	[2]48
Egypt	65	98	111	110
Ghana	162	169	125	[2]186
South Africa, Republic of	86	86	89	[2]91
Asia:				
Bahrain	135	134	135	[2]139
China:				
Mainland[e]	220	280	330	360
Taiwan	28	33	55	[2]62
India	[r]231	197	236	[2]233
Iran	34	23	28	15
Japan[6]	1,013	1,310	1,166	[2]1,114
Korea, Republic of	19	20	22	20
Turkey	[r]39	57	35	35
United Arab Emirates: Dubai	--	--	--	10
Oceania:				
Australia	256	273	290	[2]297
New Zealand	154	160	167	[2]171
Total	[r]13,787	15,093	15,510	15,979

[e] Estimate. [p] Preliminary. [r] Revised.

[1] Output of primary unalloyed ingot unless otherwise specified.

[2] Reported figure.

[3] Exports.

[4] Includes secondary unalloyed ingot.

[5] Includes primary alloyed ingot.

[6] Production of superpure aluminum (99.99% Al) is reported as follows, in short tons: 1976-4,251; 1977-5,138; 1978-4,448; 1979-4,238. Apparently this production is included in the reported total for unalloyed ingot production.

Table 16.—Aluminum: World capacity, by country[1]

(Thousand short tons)

Country	1976	1977	1978	1979
North America:				
Canada	1,175	1,175	1,175	1,175
Mexico	50	50	50	50
United States	5,193	5,193	5,197	5,282
South America:				
Argentina	66	154	154	154
Brazil	187	198	251	296
Surinam	73	73	73	73
Venezuela	55	132	209	441
Europe:				
Austria	101	101	101	101
Czechoslovakia	72	72	72	72
France	452	452	452	474
German Democratic Republic	94	94	94	94
Germany, Federal Republic of	841	841	841	841
Greece	160	160	160	160
Hungary	[r]101	[r]101	101	101
Iceland	84	84	84	95
Italy	321	321	315	353
Netherlands	293	293	293	293
Norway	[r]758	[r]769	772	772
Poland	122	122	127	127
Romania	[r]220	[r]220	220	220
Spain	240	240	439	439
Sweden	94	94	94	94
Switzerland	104	104	104	104
U.S.S.R	[r]2,675	2,695	3,085	3,230
United Kingdom	403	403	403	403
Yugoslavia	199	199	236	275
Africa:				
Cameroon	61	[r]68	68	68
Egypt	110	110	110	110
Ghana	220	220	220	220
South Africa, Republic of	88	88	88	88
Asia:				
Bahrain	132	132	132	132
China:				
Mainland	270	300	300	300
Taiwan	77	77	83	83
India	330	[r]335	390	390
Iran	55	55	55	55
Japan	1,627	[r]1,745	1,803	1,764
Korea, Republic of	20	20	20	20
Turkey	66	[r]66	66	66
United Arab Emirates, Dubai	--	--	--	149
Oceania:				
Australia	256	274	274	309
New Zealand	165	165	165	165
Total	[r]17,610	[r]17,905	18,816	19,637

[r] Revised.

[1] Detailed information on the individual aluminum reduction plants is available in a 2-part report which can be obtained from Chief, Division of Finance, Bureau of Mines, Bldg. 20, Federal Center, Denver, Colo. 80225. Part I of "Primary Alumimum Plants, Worldwide," details location, ownership, and production capacity for 1978-85, and sources of energy and aluminum raw materials for foreign and domestic primary aluminum plants, including those in centrally planned economies. Part II, summarizes production capacities for 1978-85 by smelter and country.

TECHNOLOGY

The sources of impurities in primary aluminum metal were traced from bauxite (the ore) through alumina (an intermediate aluminum raw material made from bauxite in the Bayer process) and the electrode materials and fluoride compounds used in electrolytic reduction of the alumina in the Hall-Heroult process.[5] Unlike some other metals, the quality of aluminum metal cannot be improved significantly except through elaborate means, and it is necessary to prepare a very-high-purity alumina and to use electrode materials and fluorine compounds of very high purity, in order to produce a high-quality primary metal.

A review of fluorine consumption trends in the aluminum industry indicated a continuing decline in the use of fluorine per ton of primary aluminum produced.[6] In the Hall-Heroult process fluorine is lost primarily in the fumes emitted from the electrolytic cell and by absorption into the carbon cathode or cell lining. Because high concentrations of fluorine are harmful, fumes emitted from the cell must be controlled. This factor, coupled with development of economically viable processes to recover and recycle the fluorine emitted from the cell, is a principal reason for the decline in the unit use of fluorine. The use of prebaked cathode block construction versus monolithic cathode construction also has led to declining unit consumption of fluorine because the prebaked cathodes last longer.

Spent carbon cathode linings of both types pose special disposal problems because of the fluorine content and nature of other constituents in the linings. As a consequence methods for recycling the used pot linings have been developed to varying degrees. A review of the processes being developed concluded that leaching of the spent lining with hot water, followed by removal of the dissolved fluorine compounds with calcium chloride treatment, and screening of the remaining solids to be used to make new cathodes, offered a promising method.[7]

Emission guidelines and compliance times for State environmental protection agencies to use in establishing standards of performance to control fluoride emissions from existing primary aluminum plants were published in a final guideline document.[8]

A report on recycling scrap metal, including aluminum, presented data on energy requirements for the major steps in scrap processing and identified areas for research and development.[9] Technical and economic information on recycling aluminum scrap was compiled by the Aluminum Association to aid and encourage both business and municipalities in implementing recycling programs.[10]

One of the main sources of the old aluminum-base scrap recycled in the United States is automotive scrap. The use of aluminum metal in automobiles has increased through the years, and as a result of the need to meet improved mileage standards in the future, aluminum use in automobiles is expected to continue to increase. A large part of the aluminum from automotive scrap is believed to be recovered by hand-sorting methods, but with the development of the relatively recent practice of shredding whole automobiles, a need to develop methods to recover aluminum from the other metals in the shredded product has become important. The technology for recovering aluminum from such material was reviewed.[11]

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[1] Industry economist, Section of Nonferrous Metals.

[2] Mineral specialist, Section of Nonferrous Metals.

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[8] U.S. Environmental Protection Agency. Primary Aluminum: Guidelines for Control of Fluoride Emissions From Existing Primary Aluminum Plants. EPA-450/2-78-049b, December 1979, 343 pp.

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Antimony

By T. John Rowland, Jr.,[1] and V. A. Cammarota, Jr.[2]

The consumption of antimony declined in 1978 and 1979 from that of 1977. For the fifth consecutive year, the use of antimony metal as a hardening agent in battery grid alloys decreased. Technological changes in the types of alloys used in automotive batteries have drastically reduced the use of antimony as a hardener for battery grids in recent years.

The traditional practice of pricing antimony metal on the basis of RMM and Lone Star brands, which were produced at NL Industries, Inc.'s, Laredo, Tex., smelter, was discontinued in April 1978 owing to the closing of the plant and depletion of residual stocks. Effective April 17, 1978, a new quotation was established on the basis of refined antimony in alloy. The new price, $1.75 per pound, represented the published prices of the two largest alloy producers, NL Industries and RSR Corp. This price was maintained through early 1979, when it was increased to $2 per pound, remaining at that level through the year.

Domestic mine production was at normal levels in 1978 and 1979, but metal production increased substantially in 1979 over that of 1978 because of the reactivation of the smelter in Laredo, Tex. Imports were up significantly in 1978 and 1979 over those of 1977, mainly because of higher imports of concentrate and antimony oxide.

Legislation and Government Programs.—At yearend 1979 the General Services Administration reported that Government stocks of antimony totaled 40,727 tons. The Government stockpile goal remained at 20,130 tons.

Table 1.—Salient antimony statistics

(Short tons)

	1975	1976	1977	1978	1979
United States:					
Production:					
Primary:					
Mine	886	283	610	798	722
Smelter[1]	12,189	14,618	12,827	14,110	15,062
Secondary	17,964	19,799	30,601	26,456	NA
Exports of metal and alloys	340	341	742	556	485
Imports for consumption (antimony content)	18,706	21,770	18,835	17,511	22,125
Consumption[1]	12,987	15,337	13,823	13,152	11,753
Stocks, primary antimony, all classes, (antimony content), Dec. 31	14,957	15,070	8,591	8,201	7,144
Price: New York, average cents per pound	176.58	165.26	178.00	[2]175.00	[2]196.00
World: Production	77,114	[r]75,292	72,483	72,122	79,381

[r] Revised. NA Not available.

[1] Includes primary antimony content of antimonial lead produced at primary lead refineries.

[2] Antimony price in alloy, cents per pound.

DOMESTIC PRODUCTION

MINE PRODUCTION

Domestic mine production of primary antimony in 1979 by two companies was down from that of 1978. The United States Antimony Corp. (USAC) produced antimony from the stibnite mined at the Babitt, Bardot, and Black Jack mines at Thompson Falls, Mont. In 1979, USAC increased pro-

duction of antimony to 299 tons, compared with 207 tons in 1978. The Sunshine Mining Co. operated the Sunshine mine in the Coeur d'Alene district of Idaho and produced 423 tons of antimony, a decrease of 168 tons from the 1978 output. Antimony was produced as a byproduct of the treatment of tetrahedrite, a complex silver-copper-antimony sulfide, one of the principal ore minerals in the Kellogg, Idaho, area. In June 1979, a 19% stock interest in Sunshine Holdings Corp. was sold to Arab Investors Group SA, a Luxembourg corporation.

Antimony was also produced as a byproduct in smelting primary lead from domestic concentrates. The total antimony supply from domestic mines was 1,337 tons in 1978 and 930 tons in 1979. Two primary lead refiners reported production in 1978 and 1979.

Table 2.—Antimony mine production and shipments in the United States

(Short tons)

Year	Antimony concentrate	Antimony	
		Produced	Shipped
1975	4,505	896	966
1976	1,111	283	310
1977	3,495	610	534
1978	4,231	798	863
1979	3,294	722	701

SMELTER PRODUCTION

Primary.—Production of primary antimony products in 1979 was the highest since 1974. Metal production increased after 2 years of decline, and the production of antimony oxide remained strong. The production of metal more than doubled in 1978 with the reopening of the expanded Laredo, Tex., smelter which Anzon America Inc. bought from NL Industries. ASARCO Incorporated produced and sold a small amount of metal in 1979 from its new smelter in El Paso, Tex., but mechanical problems precluded full-scale operation. ASARCO began full production at its Omaha, Nebr., antimony oxide plant in early 1979. The plant, built at a cost of approximately $2.2 million, has a rated capacity of 225 tons of antimony oxide per month and utilizes an enclosed and automated process.

The major producers of antimony oxide were Harshaw Chemical Co., Gloucester City, N.J.; Chemetron Corp., La Porte, Tex.; M&T Chemicals Inc., Baltimore, Md.; and McGean Chemical Co., Inc., Cleveland, Ohio. Producers of antimony metal included Sunshine Mining Co., Kellogg, Idaho, and USAC at Thompson Falls, Mont., which also produced sodium antimonate.

Secondary.—Production of antimony from secondary sources decreased in 1978 from that of 1977. Data were not available for 1979. Secondary smelters recovered 22,371 tons, primary smelters recovered 73 tons, and manufacturers and foundries recovered the remaining 4,012 tons. Old scrap, predominantly battery plates, was the source of most of the secondary output; new scrap, mostly in the form of drosses and residues from various sources, supplied the remainder. The antimony content of scrap is usually recovered and consumed as antimonial lead with removal or addition of antimony as required in the refining stage to meet specifications for various antimonial lead alloys.

Table 3.—Primary antimony produced in the United States

(Short tons of antimony content)

Year	Class of material produced				Total
	Metal	Oxide	Residues	Byproduct antimonial lead	
1975	3,254	7,890	595	450	12,189
1976	3,102	10,628	191	697	14,618
1977	1,877	9,907	277	766	12,827
1978	1,108	12,117	184	701	14,110
1979	2,642	12,141	--	279	15,062

Table 4.—Byproduct antimonial lead produced at primary lead refineries in the United States

(Short tons)

Year	Gross weight	Antimony content				
		From domestic ores[1]	From foreign ores[2]	From scrap	Total	
					Quantity	Percent
1975	6,029	268	182	117	567	9.4
1976	6,743	355	342	33	730	10.8
1977	7,557	598	168	134	900	11.9
1978	5,518	539	162	82	783	14.2
1979	3,750	208	71	20	299	8.0

[1] Includes primary residues and a small quantity of antimony ore.

[2] Includes foreign base bullion and small quantities of foreign antimony ore.

Table 5.—Secondary antimony produced in the United States, by kind of scrap and form of recovery

(Short tons of antimony content)

Kind of scrap	1978	Form of recovery	1978
New scrap:		In antimonial lead[1]	21,620
Lead-base	4,032	In other lead alloys	4,818
Tin-base	36	In tin-base alloys	18
Total	4,068	Total	26,456
		Value (millions)	$92.6
Old scrap:			
Lead-base	22,371		
Tin-base	17		
Total	22,388		
Grand total	26,456		

[1] Includes 78 tons of antimony recovered in antimonial lead from secondary sources at primary plants in 1978.

CONSUMPTION AND USES

Domestic consumption of primary antimony in 1979 declined for the third consecutive year. The use of antimonial lead in the manufacture of starting-lighting-ignition batteries for the automotive industry remained a major outlet, but development of maintenance-free batteries has resulted in a decline in the use of antimony metal in recent years. The lead-calcium-tin alloy in the maintenance-free battery systems uses no antimony. A reduction of 10% in battery shipments in 1979 compared with those of 1978 contributed to lower antimony usage. Antimonial lead alloys were used for solder, ammunition, chemical pumps and pipes, roofing sheets, communication equipment, and antifriction bearings.

The use of antimony in nonmetal products declined in 1979 from that in 1978. Its use in ceramics and glass has generally declined in recent years, but its use in plastics has increased substantially since 1975. Nonmetallic antimony was used in plastics both as a stabilizer and as a flame retardant. Antimony was used as a decoloring and refining agent in some forms of glass such as special optical glasses.

The use of antimony oxide as a flame retardant continued to grow in 1979. The use in plastics and textiles as a flame retardant was the major outlet. When fabrics treated with antimony oxide in an organic solvent are ignited, the flames accompanying the initial combustion are restricted or extinguished by the products of combustion.

Table 6.—Industrial consumption of primary antimony in the United States

(Short tons of antimony content)

Year	Class of material consumed						
	Ore and concentrate	Metal	Oxide	Sulfide	Residues	Byproduct antimonial lead	Total
1975	359	4,229	7,311	33	595	460	12,987
1976	640	3,375	10,397	37	191	697	15,337
1977	160	2,625	9,959	36	277	766	13,823
1978	131	2,709	9,399	28	184	701	13,152
1979	15	1,899	9,528	32	--	279	11,753

Table 7.—Industrial consumption of primary antimony in the United States, by class of material produced

(Short tons of antimony content)

Product	1975	1976	1977	1978	1979
Metal products:					
Ammunition	239	63	138	133	253
Antimonial lead	4,568	3,861	2,936	2,832	1,300
Bearing metal and bearings	402	405	265	279	235
Cable covering	23	19	16	21	--
Castings	18	24	13	15	30
Collapsible tubes and foil	9	23	16	17	24
Sheet and pipe	60	74	56	39	36
Solder	133	188	220	206	199
Type metal	75	79	83	81	37
Other	120	164	104	113	99
Total	5,647	4,900	3,847	3,736	2,213
Nonmetal products:					
Ammunition primers	14	13	13	13	23
Fireworks	10	12	9	5	6
Ceramics and glass	989	1,260	1,547	1,259	1,127
Pigments	321	415	400	410	399
Plastics	1,091	1,277	1,503	1,456	1,580
Rubber products	458	578	473	254	182
Other	658	1,330	266	165	140
Total	3,541	4,885	4,211	3,562	3,457
Flame retardant:					
Plastics	2,501	3,777	3,972	4,063	4,262
Pigments	92	183	149	33	35
Rubber	172	189	219	196	146
Adhesives	126	141	246	298	302
Textiles	748	1,065	997	990	1,143
Paper	160	197	182	274	195
Total	3,799	5,552	5,765	5,854	6,083
Grand total	12,987	15,337	13,823	13,152	11,753

Table 8.—Industry stocks of primary antimony in the United States, December 31

(Short tons of antimony content)

Stocks	1975	1976	1977	1978	1979
Ore and concentrate	8,364	7,879	1,869	1,610	1,757
Metal	1,380	1,662	1,359	1,119	1,184
Oxide	3,886	4,580	4,576	4,906	3,398
Sulfide	32	31	24	19	17
Residues and slags	921	475	516	457	730
Antimonial lead[1]	374	443	247	90	58
Total	14,957	15,070	8,591	8,201	7,144

[1] Inventories from primary sources at primary lead refineries only.

PRICES

In April 1978, Metals Week discontinued the Lone Star and RMM price quotations and began reporting a new price category of antimony in alloy. The price of antimony in alloy was established at $1.75 per pound and remained at that level through February 1979. In March, the price was increased to $2 to $2.02 per pound, where it remained to yearend. The industry price quotation for antimony trioxide was in the range of $1.64 to $1.80 per pound throughout 1978, but fell to $1.50 in February 1979. In mid-1979, the price was increased to $1.65, reflecting rising costs of raw materials. The New York dealer price for antimony metal, quoted in January 1978 at $1.05 to $1.10 per pound, gradually increased to a high in 1978 of $1.25 to $1.35 by November, but finished the year at $1.23 to $1.28. The price rose to $1.53 to $1.60 through the first 5 months of 1979, but declined to $1.45 to $1.50 in the last 4 months of the year. The European market quotation for lump ore, on a 60% antimony basis, was $16 to $18 per metric ton unit for the first 9 months of 1978, but began rising during the fourth quarter and closed at $18.50 to $19.80. Quotations generally rose in 1979 to $23 to $24.75 by yearend.

Table 9.—Antimony price ranges

Type of antimony	Price per pound	
	1978	1979
Domestic metal[1]	$1.75	$1.96
Foreign metal[2]	$1.05-1.35	$1.25-1.60
Antimony trioxide[3]	1.64-1.80	1.50-1.80

[1] Based on antimony in alloy.
[2] Duty-paid delivery, New York.
[3] Quoted in Metals Week.

FOREIGN TRADE

Total imports of antimony (antimony content) in 1979 increased compared with those of 1978. Most of the increase was due to higher imports of antimony concentrates and oxide, both of which have increased since 1977.

Imports of antimony metal from mainland China rose in 1978 and 1979 over those of 1977, making China a major supplier. The Republic of South Africa was the largest single source for imports of antimony oxide in 1978 and 1979, followed by the United Kingdom, France, and mainland China in 1978, and mainland China, France, and the United Kindom in 1979.

Imports of ore and concentrate in 1979 increased significantly over the levels of 1977 and 1978. Compared with imports in 1977, Bolivia, Canada, Chile, and Mexico provided larger quantities of antimony ore, but the Republic of South Africa supplied much less than in the past years.

Belgium-Luxembourg, mainland China, and the United Kingdom emerged as the leading sources of needle and sulfide antimony for the United States in 1978. The Republic of South Africa, which was the leading source of antimony needle and sulfide in 1977 with 83% of the total, supplied none in 1978, and mainland China supplied none in 1979.

Table 10.—U.S. imports for consumption of antimony, by country

Country	1978 Quantity (short tons)	1978 Value (thousands)	1979 Quantity (short tons)	1979 Value (thousands)
Antimony metal, including needle or liquated (antimony content):[1]				
Belgium-Luxembourg	187	$400	357	$1,005
Bolivia	349	829	672	1,581
Burma	--	--	1	2
Canada	3	55	23	162
Chile	173	326	11	28
China:				
Mainland	2,136	4,209	1,360	3,369
Taiwan	381	634	(2)	(2)
Dominican Republic	--	--	55	146
Germany, Federal Republic of	(2)	12	(2)	27
Hong Kong	--	--	28	61
Malaysia	(2)	(2)	(2)	(2)
Mexico	640	967	405	410
Peru	99	146	30	54
Spain	100	207	20	50
United Kingdom	12	37	(2)	4
Yugoslavia	99	188	77	201
Total	4,179	8,019	3,040	7,100
Antimony oxide:				
Belgium-Luxembourg	708	1,889	462	1,268
Bolivia	515	1,119	979	2,163
Canada	21	62	38	45
China:				
Mainland	1,214	2,925	1,846	4,351
Taiwan	22	52	42	95
France	2,214	5,846	1,734	4,328
Germany, Federal Republic of	20	23	4	7
Italy	355	834	141	370
Japan	334	631	124	298
South Africa, Republic of	3,033	993	7,268	2,194
Switzerland	--	--	19	122
United Kingdom	2,231	4,429	1,022	2,680
Total	10,667	18,803	13,679	17,921

[1] Includes needle or liquated (value in thousands): 1978-Belgium-Luxembourg 19 tons ($55), Canada[2] ($1), mainland China 22 tons ($33), the United Kingdom 10 tons ($31); 1979-Belgium-Luxembourg 18 tons ($90).

[2] Less than 1/2 unit.

Table 11.—U.S. imports for consumption of antimony ore, by country

Country	1978 Gross weight (short tons)	1978 Antimony content (short tons)	1978 Value (thousands)	1979 Gross weight (short tons)	1979 Antimony content (short tons)	1979 Value (thousands)
Bolivia	2,421	1,550	$1,806	2,716	1,694	$2,464
Canada	2,474	1,583	2,267	2,732	1,716	2,924
Chile	576	376	504	1,636	1,067	1,944
China, mainland	40	28	59	--	--	--
Colombia	66	47	47	35	16	28
Denmark	--	--	--	40	10	38
Honduras	6	2	2	6	2	8
Mexico	2,620	631	1,018	5,725	1,613	1,911
Peru	19	18	29	37	35	57
South Africa, Republic of	450	260	442	1,247	733	1,245
Thailand	--	--	--	857	459	777
United Kingdom	--	--	--	449	212	223
Uruguay	--	--	--	265	175	241
Total	8,672	4,495	6,174	15,745	7,732	11,860

Table 12.—U.S. imports for consumption of antimony

Year	Antimony ore			Needle or liquated		Antimony metal[1]		Antimony oxide	
	Gross weight (short tons)	Antimony content (short tons)	Value (thousands)	Gross weight (short tons)	Value (thousands)	Gross weight (short tons)	Value (thousands)	Gross weight (short tons)	Value (thousands)
1977	8,042	3,438	$6,832	259	$580	1,722	$4,536	9,641	$15,150
1978	8,672	4,495	6,174	52	121	4,127	7,897	10,667	18,808
1979	15,745	7,732	11,860	28	90	3,022	7,100	13,079	17,921

[1] Does not include alloy containing 83% or more antimony.

Table 13.—Antimony: World mine production (content of ore unless otherwise indicated), by country

(Short tons)

Continent and country	1976	1977	1978[p]	1979[e]
North America:				
Canada[e] [1]	2,535	3,500	3,300	3,300
Guatemala	1,235	1,012	254	250
Honduras	129	77	[e]110	110
Mexico[2]	2,806	2,974	2,708	2,700
United States[3]	283	610	798	[4]722
South America:				
Argentina	2	--	--	--
Bolivia[5]	[r]18,756	13,660	13,968	[4]14,351
Brazil	39	370	279	280
Peru (recoverable)	665	907	987	990
Europe:				
Austria	588	564	561	600
Czechoslovakia	[r]314	[e]330	[e]330	330
Greece	243	--	--	--
Italy	1,112	891	1,026	1,000
Spain	[r]287	543	519	540
U.S.S.R.[e]	8,500	8,700	8,700	9,000
Yugoslavia	2,228	2,478	[e]3,040	3,100
Africa:				
Algeria[e]	(6)	(6)	--	--
Morocco	1,560	1,553	2,437	2,300
Rhodesia, Southern[e]	330	330	280	280
South Africa, Republic of	[r]11,793	12,715	10,024	[4]12,958
Asia:				
Burma	[r]516	551	683	700
China, mainland[e]	13,000	13,000	14,000	17,000
Korea, Republic of	11	--	22	--
Malaysia (Sarawak)	[r]276	488	535	550
Pakistan	[r]61	104	115	120
Thailand	4,047	2,705	3,167	3,200
Turkey	[r]1,890	2,118	[e]2,610	2,700
Oceania: Australia[7]	[r]2,086	2,303	1,669	2,800
Total	[r]75,292	72,483	72,122	79,881

[e] Estimate. [p] Preliminary. [r] Revised.

[1] Partly estimated on the basis of reported value of total production.

[2] Antimony content of ores for export plus antimony content of antimonial lead and other smelter products produced.

[3] Production from antimony mines; excludes a small amount produced as a byproduct of domestic lead ores.

[4] Reported figure.

[5] Total national production. (Previous year's data represented production by COMIBOL plus exports by medium and small mines and so-called "other producers.")

[6] Revised to zero.

[7] Antimony content of antimony ore and concentrates, lead concentrates, and lead and zinc middlings.

WORLD REVIEW

Antimony was produced from ores and as a smelter byproduct in about 25 countries. Australia, mainland China, and the Republic of South Africa showed the greatest increase in production in 1979. In 1978, Japanese antimony producers increased production of antimony oxide but reduced production of antimony metal. The only antimony metal refinery in India closed in 1977. In Belgium, Metallurgie Hoboken-

Overpelt, S.A., began construction in 1978 on a new plant to recover antimony oxide from lead smelter residues. In mainland China a new mine designed to produce 3,000 tons of antimony in its first stage of development was opened in the Hochih area of Guangxi Province in 1979.

Australia.—Antimony was produced by Vam Ltd. at its Hillgrove mines near Armidale in New South Wales. The Blue Spec gold-antimony mine in Nullagine, Western Australia, closed in January 1979, and the equipment was sold.

Bolivia.—Bolivia remained the world's largest producer of antimony in 1978 and 1979. Bolivian antimony reserves were estimated to be approximately 400,000 tons at yearend 1978. Empresa Nacional de Fundiciones (ENAF) continued to produce metal and oxide for export. ENAF operated its Vinto refinery at about 75% of capacity in 1979 because of low prices for antimony. Bolivian concentrates and cobbed ore were exported to the United States, Europe, and Japan.

Canada.—Antimony metal was produced in Canada as a byproduct of lead smelting and refining. Cominco Ltd. operated a smelter and refinery at Trail, British Columbia, where antimony was recovered in the form of antimonial lead. Brunswick Mining and Smelting Corp. produced antimony metal at its lead smelter near Belledune, New Brunswick.

Consolidated Durham Mines and Resources Ltd. mined and concentrated antimony near Fredrickton, New Brunswick. The principal ore mined was stibnite. Concentrates averaging 66% antimony were exported mainly to Europe, but smaller amounts were shipped to the United States.

In British Columbia, Placer Development Ltd. and Equity Silver Mines Ltd. began construction of a mine and mill at the Sam Goosly silver-copper deposit. After startup in mid-1980, antimony production was expected to be 1,870 tons per year.

South Africa, Republic of.—Antimony concentrates were produced from the Athens, Gravelotte, Monarch, Mulati, United Jack, Weigel, and Free State mines of Consolidated Murchison Ltd. (CML). The mines are located on the northern Transvaal's "Antimony Line" in the Swaziland schists of the Murchison Range, where stibnite and other sulfides associated with gold exist in large quantities. Antimony was produced as a concentrate and as a high-grade cobbed ore. Most of CML's production was shipped to Europe and North America. Antimony Products (Pty.), Ltd. (APL), continued to produce crude antimony oxide for export using CML concentrates. APL's capacity in early 1978 was 7.2 million pounds per year of crude antimony oxide. Due to increased demand for antimony oxide, the company began installation of two new kilns in 1979 for converting the sulfide to oxide.

Thailand.—Antimony was produced in the north, central, and southern regions. The major producing Provinces were Phrae and Lampang in the North region, Kanchona Buri, Chanthaburi, Rayung, and Rat Buri in the central area, and Nakhon Si Thammarat and Surat Thani in the south. Antimony was exported mainly to Malaysia, Taiwan, Japan, India, North America, Europe, and South Korea.

Turkey.—The major producing mine, the Turhal, is situated near Tokat in central Anatolia. Substantial reserves are located in the Balikesir-Kutahya and Aydin regions. The Turkish Mineral Research and Exploration Institute (MIA) reported that reserves of antimony ore were 2.4 million tons in 1977.

Yugoslavia.—Rudarsko Topionicki Bazen Zajaca (RTB-Zajaca) operated the Rajiceva Gora antimony mine and mill on Kopaonik Mountain in Serbia. Reserves of antimony ore at Rajiceva Gora were estimated to be 10 to 15 million tons. The mine was expected to reach full ore production of approximately 300,000 tons per year by 1980. A new lead refinery under construction at Trepca will provide increased production of antimony byproduct.

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Asbestos

By R. A. Clifton[1]

Shipments of asbestos (mostly chrysotile) in 1978 from mines in the United States increased minimally from those in 1977. There was another small increase in 1979. Imports in 1978 were 4% higher than those in 1977, but decreased 10% in 1979.

U.S. apparent consumption rose 2% in 1978, but declined 9% in 1979. Canadian production in 1978 was 6% lower than that for 1977, but regained the 6% in 1979. Shipments from Canada to the United States rose 7% during 1978, but dropped 1% in 1979. Imports from Canada were 95% of total U.S. imports, and those from the Republic of South Africa accounted for 4%; these figures were 97% and 3%, respectively, in 1979.

Table 1.—Salient asbestos statistics

	1975	1976	1977	1978	1979
United States:					
Production (sales) metric tons	89,480	104,878	92,256	93,097	93,354
Value thousands	$14,220	$23,696	$25,267	$27,987	$28,925
Exports and reexports (unmanufactured) metric tons	33,061	42,564	34,896	45,290	45,850
Value thousands	$10,667	$12,791	$12,075	$20,523	$24,165
Exports and reexports of asbestos products (value) do	$60,776	$80,572	r$82,665	$119,915	$130,906
Imports for consumption (unmanufactured) metric tons	488,521	596,787	550,698	570,020	518,084
Value thousands	$111,011	$142,145	$145,146	$154,351	$135,211
Released from stockpile (unmanufactured) metric tons	6,238	501	185	--	--
Consumption, apparent[1] do	551,188	658,847	609,157	618,706	565,588
World: Production do	4,138,755	r5,086,071	r5,220,689	5,158,868	5,277,591

rRevised.
[1] Measured by quantity produced, plus imports, plus stockpile releases, minus exports.

Legislation and Government Programs.—No date was set by the Occupational Safety and Health Administration (OSHA) for the public hearings mandatory for the proposed revisions to its asbestos standard for manufacturing. The proposal for a permissible-exposure level of 0.5 fibers per cubic centimeter has been pending for 5 years until the hearings are scheduled.

On January 10, 1978, the Supreme Court dismissed an indictment against a Michigan wrecking company accused of violating the Environmental Protection Agency's (EPA) asbestos regulation. The high court ruled that the regulation was not an "emission standard" because it had no numerical limit, but rather a work practice.

On April 26, 1978, Joseph A. Califano, Secretary of the Department of Health, Education and Welfare (HEW) initiated a government asbestos warning program. Two major steps were announced: Issuance of an advisory letter to 400,000 physicians, and startup of a public information campaign aimed at workers and others possibly exposed to asbestos.

On April 28, 1978, EPA published in the Federal Register the procedures it will follow in promulgating a hazardous waste control system. Asbestos will be included among the hazardous materials covered under authority of the Resource Conservation and Recovery Act of 1976 amendment to the Solid Waste Disposal Act.

Asbestos was one of the 12 minerals selected for in-depth study as part of the presidentially directed Nonfuel Minerals Policy Study started in 1978.

At the direction of the President, the heads of the Consumer Products Safety Commission (CPSC), the Food and Drug Administration (FDA), OSHA, and EPA in August formed the Interagency Regulatory Liaison Group (IRLG) to insure that areas of shared interest and responsibility would be considered jointly. In the initial document issued by the group in 1978, asbestos was among the 24 hazardous materials of interest to a majority of members. Among other things it said, "...it appears that all four agencies have an interest in cooperation in the following areas: Standard definitions of asbestos/asbestiform, importance of size and shape of asbestos fibers, analytical methodologies used in asbestos determinations, use of asbestos, substitutes for asbestos, labeling requirements, asbestos removal and disposal techniques and procedures, levels of environmental contamination, levels of human exposure, human body burden levels, and economic impact statements developed for regulatory purposes and for monitoring activities."

Effective December 18, 1978, the Mine Safety and Health Administration (MSHA) began enforcing its new asbestos exposure regulation. The new regulation replacing the five-fiber level reads, "The 8-hour time-weighted average airborne concentration of asbestos dust to which employees are exposed shall not exceed 2 fibers per milliliter greater than 5 microns in length, as determined by the membrane filter method at 400 to 450 magnification (4-millimeter objective) phase contrast illumination."

In the Federal Register of December 4, 1978, the Department of Transportation (DOT) issued its final rule on asbestos transportation. Effective April 30, 1979, the areas of principal impact on the industry pertain to containers, designation, and incidence reports. This was modified in the March 29, 1978, Federal Register and again in the August 16, 1979, issue.

On March 16, 1979, EPA announced its voluntary program to provide technical assistance to school officials for the prevention of exposure of children to asbestos. In the Federal Register of July 13, 1979, EPA announced a regulatory program to run parallel to the voluntary program.

On October 17, 1979, both EPA and CPSC published Advanced Notices of Proposed Rulemakings in the Federal Register. CPSC proposed initially the elimination of all nonessential uses of asbestos in consumer products which might release the fibers. EPA's regulatory approach would involve a "life cycle" method of assessing risk.

On December 17, 1979, in separate notices, both the CPSC and EPA extended the comment period on the proposed rules cited above. EPA also stated: "Should EPA's evaluation of human health risks and economic impacts determine that all but essential uses of asbestos present unreasonable risk, a possible regulatory strategy may be to ban the manufacture, processing, distribution in commerce, and import of asbestos for all nonessential asbestos uses at some fixed date in the future." EPA is seeking comment on this overall regulatory approach and on an appropriate date for instituting a general use ban. Effective dates presently under evaluation range from 1985 to 1995.

H.R. 1524, Asbestos School Hazard Detection and Control Act of 1979, passed the House but not the Senate. It included this definition of asbestos: "Asbestos and asbestos material are defined in Section 10 to include materials composed entirely or in part of chrysotile, amosite, or crocidolite, and when they occur in fibrous habit, tremolite, anthophyllite, and actinolite."

Environmental Impact.—News coverage of asbestos health problems continued during 1978-79, and litigation increased. The number of law suits grew from 159 new cases in 1976, to 362 new ones in 1977, and through September 15, 1978, 530 new ones were filed, or a prorated 700-plus for the year. One $20 million suit was settled in Texas, with nearly $6 million coming from the U.S. Government. A $1 billion suit was filed in California.

The West Australian Government has decided to close down and evacuate the 150-resident town of Wittenoom because of continuing risk from airborne asbestos dust. There is apparently a very high incidence of mesothelioma and other similar diseases among present and former residents of the area in which crocidolite asbestos was mined from 1938 to 1968. In 1979, the residents were offered purchase of their property, A$750 removal expenses, and A$100 travel grant per person.

Dr. E. Cuyler Hammond, vice president for epidemiology of the American Cancer Society, presented a paper at a spring 1978 meeting of the New York Academy of Sciences in which he said that researchers failed to find any unusual incidence of cancer among people who lived near an asbestos factory 30 to 40 years ago. The research team included Dr. Irving J. Selikoff and others from the Cancer Society and Mt. Sinai Hospital. The team did a 10-year study of residents of a Paterson, N. J., area, which was the site of an asbestos plant, and another control area several miles away.

On October 24, 1979, the United Kingdom's Health and Safety Commission published a final two-volume report of the Advisory Committee on Asbestos. The 41 recommendations were the result of 3 years of study. The committee (1) reported that there was no quantitative evidence of a risk to the general public from exposure to asbestos dust; (2) placed no prohibition on the use of asbestos (with the exception of blue asbestos), expressing the view that control of any useful but hazardous material would be preferable to the ultimate sanction of prohibition; (3) recommended the consideration of alternatives and the replacement of asbestos, providing the alternative was significantly less hazardous, and (4) pointed out that this was an area in which one should proceed with caution.

Table 2.—Stockpile goals and Government inventories as of December 31

(Metric tons)

	Stockpile goals	Total inventories			Sales of excesses, 1979
		1977	1978	1979	
Amosite	23,851	[r]38,587	38,587	38,587	--
Chrysotile		[r]9,940	9,940	9,940	--
Crocidolite	--	[r]2,163	2,163	2,163	--
Total	--	[r]50,690	50,690	50,690	--

[r] Revised.

DOMESTIC PRODUCTION

Mines in the United States shipped about 1% more asbestos in 1978 than in 1977, and had another slight increase in 1979. Value increased both years. Four States produced asbestos: California was the leader, with 69% in 1978 and 74% in 1979, followed by Vermont, Arizona, and North Carolina (1978 only). Total output was 93,097 tons valued at $27,987,000 in 1978, and 93,354 tons valued at $28,925,000 in 1979.

Calaveras Asbestos Corp. was California's and the Nation's leading producer from its Copperopolis mine. Two other mines were also active in California on the Joaquin Ridge near Coalinga, Atlas Asbestos Corp. worked its Santa Cruz mine in Fresno County and Union Carbide Corp. operated its Santa Rita mine in San Benito County, both on the ridge.

The Vermont Asbestos Group's Lowell mine in Orleans County, Vt., is no longer under the management that led to the employees' acquisition. The management is headed by a local contractor, Howard A. Manosh who now controls a majority of the shares. The company remains second in the country in production. Intensive recent exploration has revealed reserves of sufficient magnitude to promise another 12 years of production.

Arizona production in 1978 was below the 1977 level, and remained low in 1979. The Jaquays Mining Corp. in Gila County had the only active asbestos mine in the State.

Powhatan Mining Co.'s mine in North Carolina was somewhat active in 1978. Some anthophyllite was mined and shipped, but there was no activity in 1979.

The Alaska Asbestos Co., jointly owned by General Crude Oil Co. (an International Paper Co. subsidiary), McIntyre Mines, Ltd., and Tanana Asbestos Corp. have an active program of drilling and engineering feasibility tests underway at the Eagle property owned by Doyon, Ltd. The work is being done by WGM, Inc. for a 5% interest. U.S. asbestos producers and mine sites follow:

State and company	County	Mine	Type of asbestos
Arizona: Jaquays Mining Corp	Gila	Chrysotile	Chrysotile.
California:			
Atlas Asbestos Corp	Fresno	Santa Cruz	Do.
Calaveras Asbestos Corp	Calaveras	Copperopolis	Do.
Union Carbide Corp	San Benito	Santa Rita	Do.
North Carolina: Powhatan Mining Co	Yancey	Hippy	Anthophyllite.
Vermont: Vermont Asbestos Group	Orleans	Lowell	Chrysotile.

Employment in U.S. asbestos mines and mills averaged about 500 persons during 1978 and 1979.

CONSUMPTION AND USES

The end use data on asbestos as reported by respondents to the Bureau of Mines questionnaire are difficult to analyze. Patterns of use that may be indicative of trends are not apparent. Compared with 1977 levels, 75% of the end uses in 1978 showed decreases in asbestos consumption; in 1979, 60% showed decreases. The asbestos used in asbestos-cement pipe increased in 1978, but decreased slightly in 1979. Use in asbestos-cement sheet decreased in 1978 and 1979. Further decreases in 1978 were in flooring products, insulation, friction products, coatings and compounds, and textiles. Other major decreases in 1979 were in packing and gaskets and in friction products.

Asbestos-cement pipe, which represented 35% of the total asbestos consumption in 1978 and 38% in 1979, and flooring products, which represented 20% and 21%, respectively, were the largest end uses of asbestos.

The sources of supply of U.S. asbestos in 1978 are shown in Figure 1.

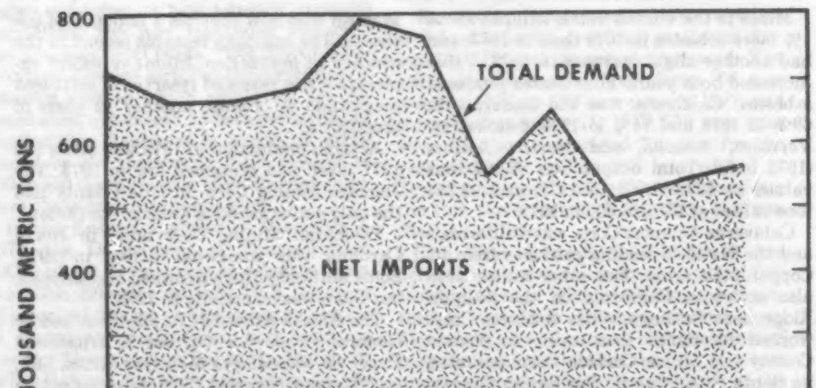

Figure 1.—U.S. sources of asbestos, 1969-1978.

Table 3.—U.S. asbestos consumption by end use, grade, and type

(Metric tons)

	Chrysotile								Crocido-lite	Amosite	Antho-phyllite	Total asbestos[1]
	Grades 1 & 2	Grade 3	Grade 4	Grade 5	Grade 6	Grade 7	Grade 8	Total chrysotile[1]				
1978												
Asbestos-cement pipe	--	--	137,000	44,700	4,100	700	--	186,500	29,700	1,200	--	217,400
Asbestos-cement sheet	--	--	4,900	11,100	12,900	6,900	--	35,700	--	400	--	36,100
Flooring products	--	--	--	58,500	--	72,400	--	126,000	--	--	--	126,000
Roofing products	--	--	300	2,200	22,200	37,400	--	61,900	--	200	--	62,100
Packing and gaskets	--	1,100	3,600	16,600	900	8,800	--	31,000	100	--	(2)	31,100
Insulation:												
Thermal	--	(2)	400	400	3,000	2,400	--	6,200	--	--	--	6,200
Electrical	--	200	--	200	(2)	400	--	800	--	--	--	800
Friction products	--	400	2,200	24,400	9,200	36,900	300	73,300	--	--	400	73,700
Coatings and compounds	--	--	300	200	1,100	17,500	--	19,100	--	(2)	--	19,100
Plastics	--	--	--	900	(2)	1,600	--	2,500	1,000	--	1,400	4,900
Textiles	200	2,700	(2)	(2)	--	--	--	2,900	--	--	--	2,900
Paper	--	100	100	1,000	3,300	4,300	--	8,700	300	--	--	9,000
Other	100	200	1,000	2,500	2,900	21,600	--	28,100	--	1,500	--	29,700
Total[1]	300	4,700	149,600	157,500	59,500	210,800	300	582,500	31,200	3,300	1,800	619,100
1979												
Asbestos-cement pipe	--	--	146,100	31,600	700	--	--	178,400	34,700	(2)	--	213,100
Asbestos-cement sheet	--	--	100	100	8,900	6,600	--	10,700	--	200	--	10,900
Flooring products	--	--	6,600	44,400	11,000	58,500	--	120,500	--	--	--	120,500
Roofing products	--	--	1,300	100	18,500	45,900	--	65,800	--	--	--	65,800
Packing and gaskets	--	1,300	3,100	8,500	400	5,800	--	19,100	100	--	--	19,200
Insulation:												
Thermal	--	--	--	200	1,800	8,100	--	10,100	--	--	--	10,100
Electrical	--	200	600	200	1,200	3,100	--	5,300	--	--	--	5,300
Friction products	--	800	3,400	16,200	5,400	35,100	--	60,900	--	--	300	61,200
Coatings and compounds	--	(2)	400	(2)	400	18,700	--	19,500	--	--	--	19,500
Plastics	(2)	(2)	100	800	(2)	1,400	--	2,300	600	--	--	2,900
Textiles	--	5,800	(2)	(2)	--	--	--	5,800	--	--	--	5,800
Paper	--	100	--	400	100	--	--	600	300	--	--	900
Other	100	600	400	2,800	9,400	10,700	--	24,000	--	1,300	--	25,300
Total	100	8,800	162,100	105,300	52,800	198,900	--	523,000	35,700	1,500	300	560,500

[1] Data may not add to totals shown because of independent rounding.

[2] Less than 50 metric tons.

PRICES

Quoted prices for Quebec asbestos, all chrysotile, rose 5.6% during 1978 and 7.1% in 1979. The last rise was effective on July 1, 1979. British Columbia asbestos chrysotile prices rose 4.0% in 1978 and 6.5% in 1979.

Prices for Vermont chrysotile asbestos rose 5.0% on January 1, 1978, and 16% on January 1, 1979. Arizona prices did not increase during 1978 or 1979. The latest prices are still those that went into effect on July 1, 1976, and quotations, f.o.b. Globe, are shown below:

Grade	Description	Per metric ton
Group 1	Crude	$3,307
Group 2	do	1,984
AAA		1,433
Group 3	Nonferrous filtering and spinning	$827- 926
Group 4	Nonferrous plastic and filtering	827- 926
Group 7	White shorts	110- 220

As of January 1, 1979, Vermont chrysotile asbestos, f.o.b. Morrisville, was priced as follows:

Grade	Description	Per metric ton
4T	Fiber	$651
5K	do	504
5R	do	428
6D	Waste	313
7D	Shorts	207
7M	do	110
7R	do	110
Hooker No. 1		1,378
Hooker No. 2		772

Quotations for Canadian (Quebec) chrysotile, f.o.b. mine, as of July 1, 1979, follow:

Grade	Description	Per metric ton
Group 2	Crude	Can$2,530
Group 3	Spinning fiber	Can$1,128- 1,770
Group 4	Asbestos-cement fiber	757- 1,114
Group 5	Paper fiber	428- 639
Group 6	Paper and shingle fiber	364- 388
Group 7	Shorts	125- 240

The latest prices for chrysotile asbestos from British Columbia, Canada, effective January 1, 1979, f.o.b. Vancouver, follow:

Grade	Description	Per metric ton
	CASSIAR MINE	
C-1	Crude	Can$3,991
AAA	Nonferrous spinning fiber	2,205
AA	do	1,764
A	do	1,157
AC	do	1,058
AK	Asbestos-cement fiber	937
AS	do	816
AX	do	739
AY	do	518
AZ	do	375
	CLINTON MINE	
CP	Asbestos-cement fiber	Can$888
CT	do	750
CY	do	518
CZ	do	375

African asbestos producers privately negotiate sales, thereby ruling out market quotations. The following tabulation shows the average value per metric ton of South African imports, regardless of grade, calculated from 1979 U.S. Department of Commerce data:

Type	1975	1976	1977	1978	1979
Amosite	$435	$508	$589	$569	$577
Crocidolite	471	571	582	624	686
Chrysotile	1,086	259	485	451	679

FOREIGN TRADE

There was an increase in the value of asbestos and asbestos products exported from the United States in 1978 over that in 1977 and a further increase in 1979. Most of the 1978 gain was accounted for by the 73% increase in the value of the unmanufactured asbestos, which had a 31% rise in tonnage. There was a dramatic increase in the value, in U.S. dollars, per metric ton from $345 to $455 in 1978, but the 1979 average was $527. The fiber share of the export dollar rose from 16% in 1977 to 24% in 1978, and was 16% in 1979.

Table 4.—Countries importing U.S. asbestos fibers and products, by type and country

(Thousand dollars)

	1978			1979		
	Unmanufactured fibers	Manufactured products	Total	Unmanufactured fibers	Manufactured products	Total
Australia	536	2,606	3,142	429	2,778	3,207
Canada	2,354	46,909	49,263	2,508	53,761	56,269
Colombia	227	3,187	3,414	364	3,324	3,688
Germany, Federal Republic of	1,563	7,072	8,635	924	4,009	4,933
Japan	3,861	2,714	6,575	4,686	2,950	7,636
Mexico	5,107	4,932	10,039	4,931	6,430	11,361
Netherlands	104	3,013	3,117	126	2,712	2,838
Saudi Arabia	119	12,501	12,620	596	11,448	12,044
United Kingdom	320	2,655	2,975	387	3,217	3,604
Venezuela	105	3,967	4,072	193	4,078	4,271
Other	5,931	29,285	35,216	8,250	33,356	41,606
Total	20,227	118,841	139,068	23,294	128,063	151,457

In 1978, the United States recovered 51% of the cost of imported asbestos by exporting and reexporting fibers and products. This was well below the 62% realized in 1977. In 1979, the value of exports and reexports exceeded the value of asbestos imports.

Table 5.—U.S. exports and reexports of asbestos and asbestos products

Products	1977		1978		1979	
	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
EXPORTS						
Unmanufactured:						
Crudes, fibers, and stucco ... metric tons	16,244	$7,433	22,153	$8,371	31,635	$12,868
Sand and refuse ... do	17,676	4,268	18,666	4,719	10,501	3,642
Asbestos fibers ... do	--	--	3,597	7,137	2,559	6,784
Total ... do	33,920	11,701	44,416	20,227	44,695	23,294
Products:						
Shingles and clapboard ... do	6,537	2,484	10,652	5,256	7,323	3,875
Other articles of asbestos ... do	([1])	([1])	14,340	11,700	17,758	13,301
Gaskets ... do	([1])	([1])	3,911	4,510	4,203	4,556
Packing and seals ... do	([1])	([1])	2,396	11,520	2,405	14,497
Insulation ... do	NA	4,671	NA	5,193	NA	4,524
Other articles, n.s.p.f ... do	([1])	([1])	NA	24,876	NA	22,806
Brake linings and disc brake pads ... do	([1])	([1])	NA	44,696	NA	55,270
Clutch facings and linings ... number	1,110,280	2,129	NA	11,090	NA	9,334
Total	XX	XX	XX	118,841	XX	128,163
REEXPORTS						
Unmanufactured:						
Crudes and fibers ... metric tons	908	364	896	296	1,039	851
Sand and refuse ... do	68	10	68	10	116	20
Total ... do	976	374	964	306	1,155	871
Products:						
Gaskets ... do	([1])	([1])	NA	37	--	--
Packing and seals ... do	([1])	([1])	NA	20	4	109
Insulation ... do	NA	NA	NA	1	--	--
Other articles, n.s.p.f ... do	([1])	([1])	NA	103	NA	68
Brake linings and disc brake pads ... do	179	197	NA	683	NA	2,492
Clutch facings and linings ... number	662	7	NA	230	NA	52
Other articles of asbestos ... metric tons	([1])	([1])	--	--	NA	22
Total	XX	XX	XX	1,074	XX	2,743

NA Not available. XX Not applicable.

[1] TSUS numbers and grouping changed in 1978; no comparable data available for 1977.

Canada remains the largest user of U.S. asbestos and products. Thirty-six percent of the value realized from these products in 1978 came from there. In 1979, Canada purchased 37% of the U.S. fibers and products sold abroad. Saudi Arabia was second in receiving U.S. asbestos and products. This country provided 9% of the U.S. export dollars in 1978 and 8% in 1979.

Other major buyers of U.S. asbestos and products were Mexico, the Federal Republic of Germany, Japan, Venezuela, and the United Kingdom, Australia, Colombia, and the Netherlands.

Canada provided 95% of the asbestos fiber imported into the United States in 1978 and 97% in 1979. The Republic of South Africa provided 4% of the imports in 1978 and 3% in 1979. Included was all of the amosite and crocidolite and most of the crudes imported. Several countries provided the remainder. Chrysotile again dominated the imported types with 97% of the total for both years. The dollar value of imported fiber in 1978 was above that of 1977, but in 1979 it was below that of 1978.

Table 6.—U.S. imports for consumption of asbestos from specified countries, by grade

(Metric tons)

Grade	Canada	Republic of South Africa	Southern Rhodesia
1977:			
Chrysotile:			
Crude	122	3,456	2,224
Spinning fibers	6,065	3,415	--
All other	509,833	2,141	313
Crocidolite (blue)	64	10,857	--
Amosite	1	528	--
Total	516,085	20,397	2,537
1978:			
Chrysotile:			
Crude	38	5,219	--
Spinning fibers	7,292	50	--
All other	535,754	1,753	--
Crocidolite (blue)	131	16,734	--
Amosite	18	1,152	--
Total	543,233	24,908	--
1979:			
Chrysotile:			
Crude	138	378	--
Spinning fibers	8,070	--	--
All other	487,499	2,235	--
Crocidolite (blue)	--	13,618	--
Amosite	--	461	--
Total	495,707	16,692	--

Table 7.—U.S. imports for consumption of asbestos (unmanufactured), by class and country

Year and country	Crude (including blue fiber) Quantity (metric tons)	Crude (including blue fiber) Value (thousands)	Textile fiber Quantity (metric tons)	Textile fiber Value (thousands)	All other Quantity (metric tons)	All other Value (thousands)	Total Quantity (metric tons)	Total Value (thousands)
1977								
Canada	187	$90	6,065	$6,224	509,833	$124,940	516,085	$131,254
Mexico	--	--	--	--	3,280	139	3,280	139
Rhodesia, Southern	2,224	2,368	--	--	313	199	2,537	2,567
South Africa, Republic of	14,842	7,721	3,415	309	2,141	1,273	20,398	9,303
Sweden	--	--	--	--	1	(¹)	1	(¹)
Taiwan	--	--	--	--	283	7	283	7
U.S.S.R	--	--	1,987	443	6,122	1,433	8,109	1,876
Total	17,253	10,179	11,467	6,976	521,973	127,991	550,693	145,146
1978								
Canada	187	105	7,292	6,491	535,754	133,146	543,233	139,742
India	--	--	--	--	39	17	39	17
Italy	383	32	--	--	164	21	547	53
Mexico	--	--	--	--	183	10	183	10
South Africa, Republic of	23,105	12,919	50	41	1,753	1,205	24,908	14,165
Sweden	--	--	--	--	20	8	20	8
U.S.S.R	--	--	--	--	1,010	324	1,010	324
Yemen, People's Democratic Republic of	--	--	--	--	44	29	44	29
Yugoslavia	--	--	--	--	36	3	36	3
Total	23,675	13,056	7,342	6,532	539,003	134,763	570,020	154,351
1979								
Australia	--	--	--	--	36	4	36	4
Austria	--	--	--	--	20	4	20	4
Canada	138	28	8,070	7,008	487,499	116,577	495,707	123,613
Germany, Federal Republic of	--	--	--	--	21	42	21	42
India	--	--	--	--	222	62	222	62
Italy	16	4	--	--	15	4	31	8
Mexico	--	--	--	--	22	5	22	5
Norway	--	--	--	--	44	7	44	7
Romania	--	--	--	--	20	4	20	4
South Africa, Republic of	13,996	9,568	--	--	2,696	1,735	16,692	11,303
South-West Africa, Territory of (Namibia)	209	143	--	--	--	--	209	143
Spain	--	--	--	--	20	4	20	4
United Kingdom	--	--	--	--	20	4	20	4
Yemen, People's Democratic Republic of	--	--	--	--	20	8	20	8
Total	14,359	9,743	8,070	7,008	490,655	118,460	513,084	135,211

¹Less than 1/2 unit.

WORLD REVIEW

A 1978 article in Industrial Minerals said that the market for mineral fibers is growing rapidly except for asbestos.[8] The constant search for asbestos substitutes was mentioned along with the legislative restrictions on its use, which effectively reduce the economic reasons for asbestos use.

The review of the 1978 world market in a Canadian trade journal attributed a 7.5% decrease in world production mainly to reduced shipments from the U.S.S.R. and the Republic of South Africa.[9] The same article predicted a 1% to 2% growth in demand over the next few years, with the growth coming mainly from the developing countries. These data on world production are shown in Figure 2.

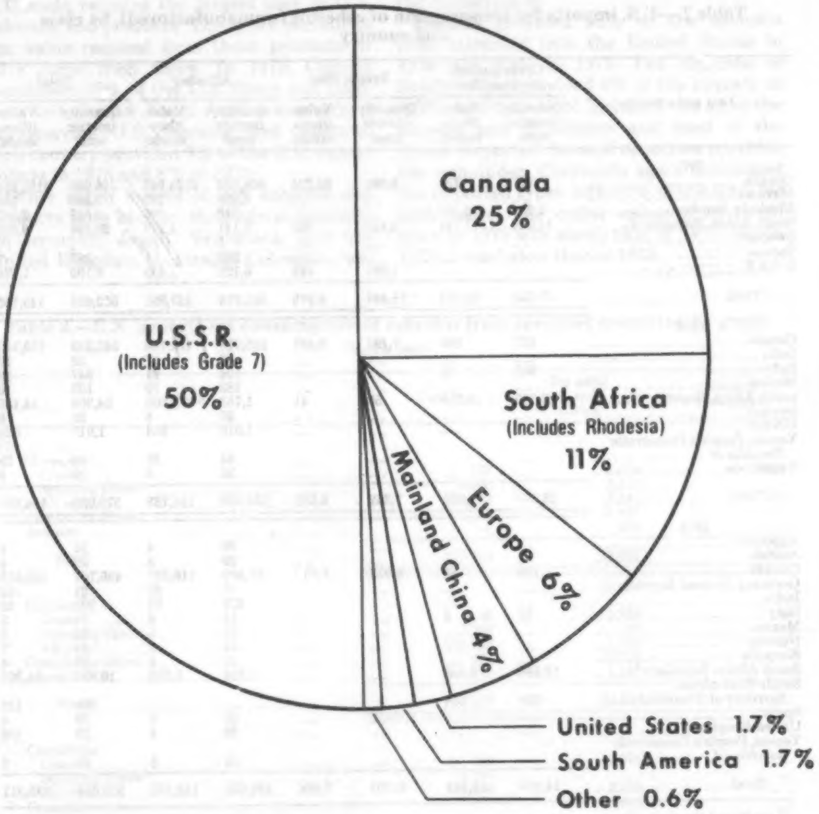

Figure 2.—World asbestos production, 1978.
(Data from work cited in footnote 3.)

Australia.—The Woodsreef Mines, Ltd., asbestos mine gained a respite from its financial problems when, at the recommendation of the Australian Industries Assistance Commission, the Cabinet extended a A$1.4 million grant. The grant is conditional on one of A$2 million from the New South Wales Government. Woodsreef Mines and its parent company, Woodsreef Minerals Corp. of Canada, are marketing a new wet milling process. A prototype mill has been proposed for February 1980 startup.

Canada.—Although Quebec shipments to over 80 countries rose 2.7% in 1978 over those in 1977, Canadian total production declined 6% during that year, only to rise nearly 9% in 1979. Cassiar Asbestos Corp.'s 3-month strike in British Columbia and the closure of their Yukon mine were contributing factors to the 1978 decline. The values received for Canadian fibers also decreased in 1978 from Can$520 million to Can$509 million. In 1979 the asbestos sold for Can$641 million. The average received per metric ton was Can$363 in 1977, Can$379 in 1978, and Can$427 in 1979.

The Quebec Asbestos Mining Association (QAMA) officially changed its name to L'Association des Mines D'Amiante du Quebec (AMAQ).

At yearend 1979, the second bill passed by the Quebec National Assembly allowing expropriation of the 54.6% of Asbestos Corp. owned by the U.S. firm General Dynamics had not been exercised. There was an injunction by the Quebec Court of Appeals against it and an appeal before the Supreme Court of Canada by General Dynamics. The Quebec Government wants to obtain this property to incorporate it into its Société National de l'Amiante.

Exploration continued at the Abitibi asbestos project near Amos in northwestern Quebec. Brinco, Ltd., the majority owner, and others including Asarco, Inc., are continuing talks that could lead to a Can$400 million facility to produce 226,800 metric tons per year.

Asbestos Corp. is still making plans for the Penhale property underground below the closed Normandie property, and is evaluating the possibility of going underground at the Asbestos Hill property on the Ungava Peninsula. The corporation announced a Can$122 million expansion and modernization program to be accomplished by 1984.

Cassiar Asbestos Corp. closed its Clinton mine in the Yukon during August of 1978 owing to depletion of reserves. There was a 3-month strike at its Cassiar pit in British Columbia beginning in September. The White Pass and Yukon Railway—for 80 years the only overland link between White Horse, Yukon, and Skagway, Alaska—may have to close because of the loss of its principal client, Cassiar's Clinton mine.

Johns-Manville Canada, Inc., is the new name of the former Canadian Johns-Manville, Ltd. The 1978 measurements of its Jeffrey pit at Asbestos, Quebec, showed it to be 1.98 kilometers east to west, 1.83 kilometers north to south, and 308 meters deep.

United Asbestos, Inc., has ended its receivership by repaying some debts and arranging a loan to cover the rest. Work on reopening the mine and mill at Midlothian, Ontario, is expected to be delayed by winter weather, postponing the reopening until the summer of 1980.

Greece.—Construction started in April of 1978 on the Zidani asbestos mine and mill near Kozani. Completion of the 100,000-ton-per-year chrysotile facility is scheduled for July 1980. There is a possibility of Arabian investment in the mine. Initial financing is by the Government's Hellenic Industrial Development Bank (ETVA) and management, by a company under its control.

Japan.—Examination of Japanese imports of asbestos for a recent 3-year period, shown in the following table, reveals a small decrease (8%) in 1977 and a major one (22%) in 1978. The reasons are not apparent. Canada remains the largest source, with the Republic of South Africa second. It appeared that the U.S.S.R. was getting ready to claim a large share of this market when its share rose to 24% in 1977, but the large drop to just 8% in 1978 leaves this premise in doubt.

Country of origin	1976		1977		1978	
	Metric tons	Percent	Metric tons	Percent	Metric tons	Percent
Canada	144,150	44	119,551	40	111,000	47
South Africa, Republic of	96,645	30	82,181	27	80,373	34
U.S.S.R	54,335	17	71,109	24	17,811	8
United States	10,094	3	9,247	3	11,784	5
Australia	4,351	1	9,503	3	7,846	3
Other	15,771	5	9,045	3	6,087	3
Total	325,346	100	300,636	100	234,901	100

Mexico.—Among the major investments announced by Industrias Penoles was the $44 million Pegaso asbestos plant in Oaxaca State. Johns-Manville Corp. will have a 40% equity in the joint venture.

South Africa, Republic of.—The asbestos industry of this nation had a mixed but generally down year in 1978 based on preliminary (10-month) data. Amosite production dropped more than 40% to about 40,000 tons; chrysotile, more than 30% to about 77,000 tons; and Cape Blue crocidolite, about 30% to 140,000 tons. Transvaal Blue crocidolite production rose nearly 67% to about 150 tons. No anthophyllite was produced. The total value of exported asbestos decreased over 17% from 1977 to 1978, but that sold locally increased by 33%.

Cape Industries, Ltd., completed the expansion and moderization of the mining and milling facilities at Pomfret in 1978. The new R10 million mill can produce 70,000 tons per year of fiber, and the mine has been expanded to produce sufficient ore for this. The future of their older Koegas mine is in doubt, and will be decided by the new owners, Transvaal Consolidated Land and Exploration, Ltd. (TCL). This company now owns all of the asbestos mines acquired by Cape Industries since it started mining in the Republic of South Africa in 1893.

In 1979, the South Africa Geological Survey revised its asbestos reserve estimate up to 22 million tons, an increase of over 180%.

Sudan.—Johns-Manville Corp. has been awarded two asbestos exploration concessions. Only one, in Qala-el-Nahl near the Ethiopian border is believed to have commercial possibilities. Other partners in the venture are the Sudan Textile Industry (Sudanese Government-owned) and the Gulf International Group of Kuwait. It is hoped that a $120 million facility yielding 100,000 tons per year will result with the Sudanese Government getting 49% of the profits.

Turkey.—A recent estimate put Turkey's asbestos reserves at nearly 5 million tons.

United Kingdom.—Imports of asbestos into the United Kingdom in 1978 were only 93% of those in 1977. Most of the decrease was in fiber from Swaziland, which went from 12% to 1% of the total. Canada and

Table 8.—Asbestos: World production, by country

(Metric tons)

Country[1]	1976	1977	1978^{p}	1979^{e}
North America:				
Canada (shipments)	1,536,091	1,517,360	1,421,298	^{2}1,501,000
Mexico	1	--	--	--
United States (sold or used by producers)	^{r}104,873	92,256	93,097	^{2}93,254
South America:				
Argentina	889	686	697	700
Brazil	92,703	92,773	122,815	120,000
Europe:				
Bulgaria^{e}	^{r}300	^{r}500	500	500
Italy	^{r}164,788	149,327	135,402	130,000
U.S.S.R.^{e}	2,290,000	^{r}2,400,000	2,435,000	2,470,000
Yugoslavia	^{r}12,830	9,036	10,360	10,500
Africa:				
Egypt	1,096	478	349	350
Rhodesia, Southern^{e}	165,000	200,000	225,000	250,000
South Africa, Republic of	369,840	380,164	257,325	^{2}249,187
Swaziland^{3}	41,847	38,046	36,951	38,000
Asia:				
Afghanistan	13,260	^{e}13,000	^{e}18,000	4,000
China:				
Mainland^{e}	^{r}150,000	200,000	250,000	250,000
Taiwan	853	673	2,031	2,000
Cyprus	34,518	36,684	34,342	36,000
India	^{r}24,119	22,177	19,100	20,000
Japan	7,706	6,719	^{e}6,720	8,000
Korea, Republic of	4,762	6,180	13,616	14,000
Thailand	15	4	--	--
Turkey	^{r}9,941	2,975	13,272	10,000
Oceania: Australia	^{r}60,642	50,601	62,383	70,000
Total	^{r}5,086,071	5,220,639	5,153,868	5,277,591

^{e}Estimate. ^{p}Preliminary. ^{r}Revised.

[1] In addition to the countries listed, Czechoslovakia, North Korea, and Romania also produce asbestos, but output is not officially reported, and available general information is inadequate for the formulation of reliable estimates of output levels.

[2] Reported figure.

[3] Exports.

the Republic of South Africa furnished 93% of the imports in 1978. Late in 1979, the United Kingdom Advisory Committee on Asbestos published its third and final report. The report recommended a "control limit" for human exposure at the level of 1 fiber per milliliter of air for chrysotile, 0.5 fiber for amosite, 0.1 fiber for crocidolite, and a statutory ban on the importation of crocidolite.

U.S.S.R.—Work began in 1978 on the Kiyembay asbestos mining and enrichment combine, and production started in 1979. This facility in Orenburg, Oblast, has a design capacity of 250,000 tons per year of fiber. The new V. I. Lenin combine in the Tuva A.S.S.R. commenced production in 1979, and probably produced 120,000 tons in that year.

Yugoslavia.—With the investment of about Din300 million in new facilities, the asbestos mine at Bosansko Petrovo Selo, Bosnia-Hercegovina, raised its fiber output from 5,000 to 26,000 tons per year.

TECHNOLOGY

In 1978 and 1979, as in the previous few years, the majority of the research connected with asbestos had to do with health effects. Only preliminary results are available from the National Institute of Environmental Health Sciences (NIEHS) study on the carcinogenicity of ingested asbestos. These suggest that ingested asbestos is less dangerous than inhaled asbestos.

A special committee on asbestosis of the Quebec Workmen's Compensation Board studied the medical files of 6,785 workers employed by the asbestos mining companies during the 15 months preceding December 31, 1976. The committee reported asbestosis in varying degrees in 161 workers, or 2.37%. AMAQ, in further analyzing the data, said that the incidence of asbestosis is related to exposure, and that the workers who had it had worked for decades under the more primitive asbestos extraction processes that prevailed earlier. AMAQ concluded that new technology and industrial hygiene programs are resulting in generally improved health conditions.

In an article in *Nature* magazine, researchers demonstrated a probable reason why cigarette smoking and asbestos exposure are synergistic in promoting lung cancer.[4] They report that a carcinogen found in cigarette smoke, benzo(a)pyrene, is readily adsorbed on asbestos. It remains there in the more soluble and more dangerous "structured" form, rather than linking with other molecules in the "structureless," less soluble "excimer" form.

In April of 1978, Battelle Institute was given an EPA grant to evaluate sealants to inhibit asbestos fibers from entering the atmosphere, and in May of that year Mt. Sinai Medical School's Environmental Health Laboratory had finished a project for NIEHS that demonstrated that water-based vinyl polymer coatings would effectively inhibit asbestos fibers from entering the atmosphere from walls and ceilings.

An article in an international publication describes in detail the durability of asbestos-cement pipe.[5] Sewer pipe laid in Dieppe, France, in 1932 and dug up in 1975, had lost 2 millimeters of wall thickness along the inside bottom, showed no traces of wear or chemical attack on the outside, and still exceeded current standards. Pressure pipe used in the Graz, Austria, water system between 1933 and 1973 increased in strength and safety during that periods due to a combination of factors. Forty-two-year old pressure pipe recovered in Heilbronn, Germany, was unimpaired and strength values exceeded current standards.

Substitutes.—The environmental problems associated with asbestos continue to exert pressure from the marketplace for substitutes. A recent article looked at the whole mineral fiber picture; included with asbestos was rockwool, fiberglass, and alumino-silicate fibers.[6] The article concluded that the mineral fiber market (with the exception of asbestos) is growing rapidly, and that asbestos was losing some of its asbestos-cement market to the alkali-resistant glass fibers and alternative products such as glass-fiber-reinforced plastics. The article included a table illustrating the growth of mineral fiber production in Europe that showed a 13% growth from 1975 to 1976.

There were two different approaches to using polypropylene fibers as asbestos substitutes. Shell International Chemical Corp. announced their fibers "Carifil" that has mineral additives such as clays, chalks, barium sulfate, titanium dioxide or diatomites partially imbedded in the surface of the branched fibers. Shell hopes to capture some of the asbestos building product market. A research team at Surrey University in the United Kingdom claims that its polypropylene-reinforced cement invention produces a material as strong and durable as asbestos-cement products and economically comparable. However, the material cannot be made on conventional asbestos-cement machinery.

Rockwool International AJS of Denmark has developed an alkali-resistant inorganic fiber reportedly excellent reinforcing properties. PPG Corp. has developed a texturized glass fiber for which it claims improved breaking strength and better retention of strength under heat than asbestos textiles.

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[1] Physical scientist, Section of Nonmetallic Minerals.

[2] Industrial Minerals (London). Mineral Fibres—A Review. No. 133, October 1978, pp. 19-31.

[3] Bulletin, L'Association des Mines D'Amiante du Quebec, v. 3, No. 1, January/February 1979, p. 5.

[4] Lakowicz, J. R. and J. L. Hyden. Nature. V. 275, September/October 1978, p. 446.

[5] International Asbestos Cement Review. Asbestos Cement Conduits After Forty Years. V. 23, No. 7, July 1978, pp. 71-72.

[6] Work cited in footnote 2.

Barite

By David E. Morse[1]

Domestic production of barite declined to 1.94 million tons in 1979 after a record-setting 2.11 million tons in 1978. Nevada continued to lead all States with a reported production of 1.79 million tons of barite in 1978 and 1.73 million tons in 1979. Other principal producing States in 1979 were Missouri and Georgia. Imports of crude barite continued to increase, reaching 1.29 million tons in 1978 and 1.49 million tons in 1979. The principal use for barite, as a weighting agent in oil- and gas-well drilling muds, accounted for 92% of total U.S. consumption in 1978 and 94% in 1979. Oil- and gas-well drilling increased 5.3% to a record 238.6 million feet in 1979; barite used by the drilling industry increased to 2.84 million tons breaking the record set in 1978.

Table 1.—Salient barite and barium-chemical statistics

(Thousand short tons and thousand dollars)

	1975	1976	1977	1978	1979
United States:					
Barite:					
Primary (sold or used by producers)	1,318	1,234	1,494	2,112	[p]1,937
Value	$21,200	$28,689	$30,264	$43,981	[p]$48,024
Exports	57	41	50	39	109
Value	$2,871	$2,871	$3,436	$2,724	$10,861
Imports for consumption (crude)	634	905	955	1,291	1,489
Value	$8,541	[1]$24,849	[1]$25,787	[1]$40,525	[1]$64,072
Crushed and ground (sold or used by producers)	1,807	2,204	2,598	2,702	3,019
Value	$73,075	$93,283	$110,409	$123,433	$168,096
Barium chemicals (sold or used by producers)	48	52	56	55	50
Value	$15,556	$19,698	$28,151	$24,018	$26,063
World: Production	5,419	[r]5,736	[r]6,392	7,511	[e]7,610

[e]Estimate. [p]Preliminary. [r]Revised.

[1]C.i.f. values reported. Customs values were reported in prior years.

DOMESTIC PRODUCTION

In 1979, primary barite production was reported from 32 mines: 16 in Nevada, 7 in Missouri, 2 each in Georgia, Illinois, and Tennessee, and 1 each in Arkansas, Montana, and New Mexico. New Mexico showed production for the first time since 1965. Nevada continued to be the leading producing State in both 1978 and 1979. The other producing States in descending order of production in 1979 were Arkansas, Missouri, Georgia, Montana, Illinois, Tennessee, and New Mexico. There was some barite mined in Alaska, but the sole producer declined to report production.

The term "primary barite" is the first marketable product, and includes crude or run-of-mine barite, flotation concentrates, and other beneficiated material such as washer, jig, or magnetic separation concentrates. Run-of-mine barite sold or used by producers represented 51% of total production in 1978 compared with 67% of the 1979 production total; other beneficiated material made up 45% of the total in 1978 compared with 29% of the 1979 total; flotation concentrate represented 4% of total production in 1978-79.

The leading producers of domestic barite in 1979 were (in alphabetical order) Baroid Div., NL Industries, Inc., with mines in Missouri and Nevada; Dresser Minerals Div., Dresser Industries, Inc., with mines in Missouri and Nevada; IMCO Services Div., Halliburton Co., with mines in Nevada; and Minerals Div., Milchem, Inc., with mines in Missouri and Nevada.

Domestic and/or imported barite was ground at 41 plants in 11 States during 1979. Texas (eight plants), Louisiana (six plants), and Nevada (five plants) each produced over 700,000 tons of ground barite in 1979; total ground barite production in these three States was 2.48 million tons. No other State produced over 150,000 tons of ground barite in 1979. Other States with grinding plants in 1979 were Missouri with six operations, Utah with five; California with three; Arkansas, Georgia, and Illinois, two each; and Montana and Tennessee, one each.

In 1978, a joint drilling program conducted by New Riverside Ochre Co. and Paga Mining Co., both of Centerville, Ga., delineated additional ore reserves on a jointly held property in northwestern Georgia.

In 1978, Milchem conducted a drilling program at its Fancy Hill property in Montgomery County, Ark. Work was conducted in 1979 to bring the mine and mill onstream by late 1980. Production during the estimated 11-year lifetime of the mine was projected at about 460,000 tons per year of ore, which would yield approximately 200,000 tons per year of finished product.

NL Baroid was in the process of preparing its Sun Valley mine on the Old Soldier property in Blaine County, Idaho, for production. Startup had been reported in late 1979 but no shipments were made during the year. The mine was scheduled to ship approximately 30,000 tons of barite in its first year of operation. By the time a concentration plant is completed near Hailey, Idaho (1982), NL Baroid plans to ship 100,000 tons of crude ore and finished products annually.

In Nevada, Dresser Minerals was expanding production capacity of its Greystone mine in 1979 and IMCO increased production from the Clipper mine after completing an extensive stripping program in 1978. Chromalloy American Inc., doubled the capacity of its Dry Creek jig plant north of Wells.

New grinding plants and additions to existing facilities were built and under construction in 1979. Concentrated Mud Chemicals Inc., completed a two-mill grinding facility at Corpus Christi, Tex. IMCO was expanding the capacity of its Houma, La., and Brownsville, Tex. plants. Milchem added a new mill to its New Orleans, La., plant and started construction on new grinding plants at Clifton, Okla., and Galveston, Tex. Oil Base, Inc., a subsidiary of Hughes Tool Co., planned to complete a new grinding plant at Houma, La., in 1980. NL Baroid expanded its New Orleans, La., grinding plant and rehabilitated its Blackwell, Mo., jigging-washing facility. NL Baroid had expanded the capacity of its Corpus Christi grinding plant in 1978.

In 1978, a Bureau of Mines report was released that includes 19 tables of data that show domestic barite production, consumption, and imports and also world barite output for the years 1880 to 1976.[2]

Table 2.—Barite sold or used by producers in the United States, by State

(Thousand short tons and thousand dollars)

State	1977		1978		1979	
	Quantity	Value	Quantity	Value	Quantity	Value
Missouri	117	4,061	121	4,661	89	3,679
Nevada	1,158	18,329	1,788	30,034	1,734	34,320
Other States[1]	219	7,874	202	9,286	p114	p10,025
Total	1,494	30,264	[2]2,112	43,981	p1,937	p48,024

pPreliminary.

[1] Includes Arkansas, Georgia, Idaho, Illinois, Montana, New Mexico, and Tennessee.

[2] Data do not add to total shown because of independent rounding.

Table 3.—Crushed and ground barite sold, by State

(Thousand short tons and thousand dollars)

State	1978			1979		
	Number of plants	Quantity	Value	Number of plants	Quantity	Value
Louisiana	6	841	37,581	6	847	48,076
Missouri	6	163	12,504	6	139	6,931
Nevada	5	500	14,241	5	728	20,843
Texas	8	830	39,971	8	905	55,834
Utah	5	144	4,056	5	143	11,465
Other States[1]	8	225	15,074	11	256	24,948
Total[2]	38	2,702	123,433	41	3,019	168,096

[1] Includes Arkansas, California, Georgia, Illinois, Montana, and Tennessee.
[2] Data may not add to totals shown because of indpendent rounding.

CONSUMPTION AND USES

Total sales of crushed and ground barite continued at record high levels in both 1978 and 1979. Barite for use as a weighting agent in oil- and gas-well drilling fluids continued to be the largest end use, accounting for 92% of total sales volume in 1978 and 94% of total sales volume in 1979. Total oil- and gas-well drilling footage increased 7.5% to 226.6 million feet in 1978 compared with the 210.8 million feet drilled in 1977. An additional increase of 5.3% to a record 238.7 million feet was reported in 1979. An average of 22 pounds of barite per foot of drilling was consumed in 1978; the 1979 average increased to 23 pounds per foot of drilling.

Sales of barite for all other uses declined in 1979 compared with 1978. Sales of barium chemicals declined in both 1978 and 1979. The data in table 4 are mainly for ground barite, but include the relatively small quantity of crushed barite that is primarily used by the barium-chemical industry. Other uses of ground barite (excluding well-drilling) included filler in paint, plastics, paper, and rubber; flux, oxidizer, and decolorizer in glass manufacture; and miscellaneous uses such as heavy concrete aggregate, foundry uses, and other unspecified uses.

The most important barium chemical produced in 1978-79 was precipitated barium carbonate, which was a raw material for producing many other barium compounds. It was also used in brick and tile manufacture, television tubes, barium ferrite manufacture, and for many other purposes. The average value of barium carbonate was approximately $322 per ton in 1978 and $382 per ton in 1979.

Table 4.—Crushed and ground barite sold, by use[1]

(Thousand short tons and thousand dollars)

Use[2]	1977		1978		1979	
	Quantity	Value	Quantity	Value	Quantity	Value
Barium chemicals	81	3,645	86	5,363	74	6,124
Glass	W	W	36	829	W	W
Filler or extender:						
Paint	50	7,206	61	10,247	37	6,201
Rubber	W	W	(3)	(3)	(3)	(3)
Other filler	31	4,198	38	4,719	27	2,738
Well drilling	2,372	91,448	2,474	102,151	2,843	152,096
Other uses	59	3,917	6	125	37	987
Total[4]	2,593	110,409	2,702	123,433	3,019	168,096

W Withheld to avoid disclosing company proprietary data; included with "Other uses."
[1] Includes imported barite.
[2] Uses reported by producers of ground and crushed barite, except for barium chemicals.
[3] Withheld to avoid disclosing company proprietary data; included with "Other filler."
[4] Data may not add to totals shown because of independent rounding.

Table 5.—Barium chemicals produced and sold by producers in the United States in 1978 and 1979[1]

Barium chemical	1978				1979			
	Plants[2]	Production (short tons)	Sold by producers		Plants[2]	Production (short tons)	Sold by producers	
			Quantity (short tons)	Value (thousands)			Quantity (short tons)	Value (thousands)
Barium carbonate	4	36,000	35,000	$11,266	4	31,240	31,450	$12,039
Barium chloride	3	W	W	W	3	W	W	W
Barium hydroxide	3	W	W	W	3	W	W	W
Black ash	2	W	W	W	2	W	W	W
Blanc fixe	1	W	W	W	1	W	W	W
Other barium chemicals	4	28,400	20,100	12,752	4	23,750	18,600	14,024
Total	6	64,400	55,100	24,018	6	54,990	50,050	26,063

W Withheld to avoid disclosing company proprietary data; included with "Other barium chemicals."

[1] Only data reported by barium-chemical plants that consume barite are included. Partially estimated.

[2] A plant producing more than one product is counted only once.

Table 6.—U.S. hydrocarbon well-drilling and barite consumption

Year	Barite used for well drilling (thousand short tons)	Wells drilled (thousands)[1]				Successful wells (percent)	Average depth per well (feet)	Average barite per well (short tons)
		Oil	Gas	Dry holes	Total			
1960	920	22.23	5.13	18.19	45.55	60.1	4,217	20.20
1961	942	21.41	5.46	17.38	44.25	60.7	4,285	21.29
1962	934	21.73	5.35	17.08	44.16	61.3	4,408	21.15
1963	907	20.14	4.57	16.76	41.47	59.6	4,405	21.87
1964	931	19.91	4.69	17.69	42.29	58.2	4,431	22.01
1965	987	18.07	4.48	16.23	38.77	58.2	4,510	25.46
1966	1,022	16.78	4.38	15.23	36.38	58.1	4,478	28.09
1967	965	15.33	3.66	13.25	32.23	58.9	4,385	29.94
1968	1,006	14.33	3.46	12.81	30.60	58.1	4,738	32.88
1969	1,235	14.37	4.08	13.74	32.19	57.3	4,881	38.37
1970	1,119	13.02	3.84	11.26	28.12	60.0	4,952	39.79
1971	1,044	11.86	3.83	10.16	25.85	60.7	4,806	40.39
1972	1,183	11.31	4.93	11.06	27.29	59.5	4,932	43.35
1973	1,326	9.90	6.39	10.31	26.59	61.2	5,129	49.87
1974	1,440	12.78	7.24	11.67	31.70	63.2	4,750	45.43
1975	1,638	16.41	7.58	13.25	37.24	64.4	4,685	43.98
1976	1,986	17.06	9.09	13.62	39.77	65.7	4,571	49.94
1977	2,372	18.91	11.38	14.69	44.98	67.3	4,687	52.74
1978	2,474	17.76	12.93	16.25	46.93	65.4	4,829	52.72
1979	2,763	19.38	14.68	15.75	49.82	68.4	4,791	55.46

[1] Includes exploratory and development wells; excludes service wells, stratigraphic tests, and core tests.

Source: U.S. Department of Energy, Energy Information Administration.

PRICES

The total reported value of domestically produced barite was $48 million in 1979; the average value was $24.80 per ton, compared with the 1978 average value of $20.83 per ton. The average value per ton of ground barite from Texas and Louisiana was $46.41 in 1978 and $59.28 in 1979. The prices listed in table 7 are from trade publications; they serve as a general guide but do not necessarily reflect actual transactions.

Table 7.—Barite price quotations

Item	Price per short ton[1]	
	1978	1979
Barite:[2]		
Chemical, filler, glass grades, f.o.b. shipping point, carlots:		
Handpicked, 95% $BaSO_4$, not over 1% Fe	$46.50-$55.00	$66.00
Magnetic or flotation, 96% to 98% $BaSO_4$, not over 0.5% Fe	60.00- 70.00	60.00- 70.00
Water-ground, 95% $BaSO_4$, 325 mesh, 50-pound bags	80.00- 96.00	80.00-133.00
Drilling-mud grade:		
Dry ground, 83%-93% $BaSO_4$, 3%-12% Fe, specific gravity 4.20-4.30, f.o.b. shipping point, carlots	71.00- 78.00	70.00- 90.00
Crude, imported, specific gravity 4.20-4.30, f.o.b. shipping point	31.00	19.00- 47.00
Barium chemicals:[3]		
Barium carbonate:		
Precipitated, bulk, carlots, freight equalized	250.00-325.00	[4].206
Electronics grade, bags, same basis	335.00	335.00
Barium chloride:		
Purified crystals, 400 pound drums, works (per pound)	1.24	1.24
Technical crystals, bags, carlots works	300.00	300.00
Anhydrous, bags, carlots, same basis	400.00	400.00
Barium hydrate:		
Mono, 80-pound bags, carlots, delivered (100 pounds)	34.25	--
Mono, 55-pound bags, carlots, delivered (100 pounds)	--	39.50
Barium sulfate:		
Blanc fixe, technical grade, bags, carlots	430.00	430.00
USP, X-ray diagnosis grade, powder, 250-pound drums, 1,250-pound lots (per pound)	.25	.24-.25
Barium sulfide (black ash) drums, carlots, works	115.00-150.00	115.00-150.00

[1] Unless otherwise noted.
[2] Engineering and Mining Journal. V. 179, No. 12, December 1978, p. 46, and V. 180, No. 12, December 1979, p. 23.
[3] Chemical Marketing Reporter. V. 214, No. 26, Dec. 25, 1978, p. 27, and V. 216, No. 27, Dec. 31, 1979, p. 27.
[4] Changed to per pound price in 1979.

FOREIGN TRADE

Barite exports were 37,000 tons in 1978 and 106,000 tons in 1979. The average export value per ton was $64.74 in 1978 and $100.77 in 1979. Canada was the largest importer of U.S. barite in 1978 with imports of 17,000 tons and the second largest importer in 1979 with imports of 36,000 tons. Mexico was the largest importer of U.S. barite in 1979 with imports of nearly 62,000 tons; Mexican imports were 1,062 tons in 1978.

U.S. imports of crude barite rose to a record high of 1,489,000 tons in 1979; 1,291,000 tons were imported in 1978. The average value of these imports was $43.02 per ton (c.i.f.) in 1979 and $31.39 per ton in 1978. The principal source countries and the average c.i.f. value per ton in 1979 were Peru, $34.85; China (mainland), $52.75; India, $47.86; and Ireland, $30.93. China and India were the two major entrants in the U.S. barite market in 1978; both countries have large domestic barite reserves.

Most of the imported crude barite was drilling-mud-grade and entered the United States through customs districts along the gulf coast in 1978-79. This reflects the concentration of domestic barite grinding plants near the gulf and the nearness to the largest U.S. drilling mud market. The import distribution by district in 1979 was (1978 in parenthesis): New Orleans, La., 45% (50%); Houston, Tex., 21% (15%); Galveston, Tex., 17% (19%); Laredo, Tex. (Port of Brownsville, Tex.), 13% (11%); and Port Arthur, Tex. (Port of Lake Charles, La.), 3.6% (5%).

Ground barite imports increased to 25,600 tons in 1979 compared with 21,000 tons in 1978 and 9,000 tons in 1977. India, Singapore, and Mexico were the primary suppliers of ground barite in 1979. Imports of natural ground witherite were 873,022 pounds valued at $137,952 in 1979. These imports of witherite, mainly from the Federal Republic of Germany, were probably precipitated (manufactured) barium carbonate since there has been no reported production of witherite since 1969.

U.S. imports of barium chemicals increased to 35,000 tons in 1979 compared with 32,000 tons in 1978. Barium carbonate and blanc fixe accounted for 59% of the total imports of barium chemicals and 58% of the total value of imported barium chemicals in 1979. The Federal Republic of Germany was the leading source country for lithopone, blanc fixe, hydroxide, carbonate, and a major supplier of the chloride in 1979. China, France, Italy, and the U.S.S.R. were the other major U.S. sources of barium chemicals in 1979.

Table 8.—U.S. exports of natural barium sulfate and carbonate

Country	1977		1978		1979	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Angola	--	--	--	--	256	$58
Argentina	394	$19	155	$37	60	27
Bangladesh	--	--	--	--	25	5
Barbados	--	--	--	--	451	59
Belize	500	44	--	--	--	--
Brazil	146	15	1,125	55	64	5
Cameroon	600	61	--	--	--	--
Canada	31,485	1,782	19,790	1,180	38,348	2,488
Chile	33	1	17	2	1,538	152
Colombia	--	--	804	92	--	--
Costa Rica	--	--	3	1	--	--
Dominican Republic	28	1	--	--	--	--
Egypt	--	--	3,163	198	47	4
France	51	11	242	44	14	13
Gabon	--	--	115	9	--	--
Guatemala	--	--	528	47	4,084	438
Haiti	--	--	--	--	50	2
Hong Kong	40	2	--	--	--	--
Indonesia	--	--	121	6	--	--
Italy	66	3	171	23	--	--
Japan	27	4	455	47	20	5
Korea, Republic of	148	6	4	8	--	--
Mexico	10,782	1,021	1,694	181	62,181	7,426
Netherlands	88	4	--	--	--	--
Netherlands Antilles	204	16	25	1	--	--
New Zealand	638	67	1	3	--	--
Nicaragua	--	--	224	20	--	--
Paraguay	1,101	88	--	--	--	--
Philippines	33	7	303	46	45	4
Seychelles	--	--	--	--	700	100
South Africa, Republic of	79	6	3	14	16	5
Suriname	--	--	1,062	111	--	--
Switzerland	--	--	15	1	--	--
Taiwan	147	6	--	--	--	--
Trinidad and Tobago	2,500	220	4,411	357	(1)	1
United Kingdom	--	--	198	12	824	41
Venezuela	199	28	4,002	195	117	28
Yugoslavia	--	--	41	4	--	--
Zaire	262	24	--	--	--	--
Other	--	--	22	30	--	--
Total	49,551	3,436	38,694	2,724	[2]108,841	10,861

[1] Less than 1/2 unit.

[2] Data do not add to total shown because of independent rounding.

Table 9.—U.S. exports of lithopone

Year	Quantity (short tons)	Value (thousands)
1976	779	$937
1977	435	698
1978	NA	NA
1979	NA	NA

NA Not available.

Table 10.—U.S. imports for consumption of barite, by country

Country	1977 Quantity (short tons)	1977 Value[1] (thousands)	1978 Quantity (short tons)	1978 Value[1] (thousands)	1979 Quantity (short tons)	1979 Value[1] (thousands)
Crude barite:						
Brazil	--	--	--	--	5,412	$242
Canada	77,887	$2,494	36,449	$1,075	2,185	69
Chile	26,802	992	195,377	3,267	142,466	6,826
China:						
Mainland	--	--	50,009	2,034	233,569	12,322
Taiwan	--	--	--	--	1,857	108
France	--	--	6,441	341	--	--
Germany, Federal Republic of	--	--	--	--	1	1
Greece	16,800	346	13,228	711	--	--
Guatemala	--	--	1,475	69	2,580	127
India	--	--	13,227	552	204,753	9,800
Ireland	211,417	4,949	217,754	5,551	170,444	5,272
Malaysia	3,227	65	--	--	--	--
Mexico	115,164	2,263	111,808	2,338	134,569	4,269
Morocco	73,967	2,492	129,938	4,994	133,346	7,256
Peru	267,066	6,647	383,264	10,252	338,452	11,794
Spain	--	--	--	--	1,719	158
Thailand	74,723	2,187	95,164	2,763	117,982	5,828
Tunisia	--	--	11,023	492	--	--
Turkey	87,762	3,352	7,617	326	--	--
United Kingdom	--	--	18,204	760	--	--
Total	954,815	25,787	1,290,973	40,525	1,489,285	64,072
Ground barite:						
Belgium-Luxembourg	6	1	16	5	6	2
Canada	22	2	5,448	660	990	96
China, mainland	--	--	--	--	21	4
Colombia	262	2	--	--	--	--
Germany, Federal Republic of	1	1	2	3	24	8
India	--	--	--	--	11,024	803
Mexico	9,206	116	383	17	4,688	277
Morocco	--	--	3,417	220	--	--
Singapore	--	--	11,813	782	8,820	1,016
United Kingdom	--	--	--	--	8	3
Venezuela	--	--	--	--	62	6
Total	9,497	122	21,079	1,687	[2]25,643	[2]2,215

[1] C.i.f. value.

[2] Excludes 4,292 tons valued at $12,000 from Japan believed to be improperly categorized.

Table 11.—U.S. imports for consumption of barium chemicals

Year	Lithopone		Blanc fixe (precipitated barium sulfate)		Barium chloride		Barium hydroxide	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1976	69	$25	7,971	$2,643	3,425	$690	2,422	$1,090
1977	65	27	8,729	3,069	5,384	1,170	2,448	1,222
1978	142	58	9,424	4,160	5,287	1,173	3,138	1,539
1979	1,535	662	9,352	4,152	6,839	1,396	3,912	2,009

Year	Barium nitrate		Barium carbonate precipitated		Other barium compounds	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1976	530	$122	2,420	$423	86	$102
1977	899	197	6,911	1,391	395	256
1978	468	123	10,712	2,465	2,987	1,196
1979	517	117	11,596	2,770	1,540	783

Table 12.—U.S. imports for consumption of crude, unground, and crushed or ground witherite

Year	Crude, unground		Crushed or ground	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1976	6	$5	278	$56
1977	--	--	518	108
1978	--	--	1,809	387
1979	5	1	436	105

WORLD REVIEW

World barite production increased 1.7% to 7.6 million tons in 1979 after an increase of 17.5% or 1.1 million tons in 1978. U.S. output was 28.1% and 25.4% of the world total respectively in 1978 and 1979.

Australia.—Baroid Australia Pty., Ltd., began operations in 1978 at its Davisvale, Northern Territory mine.[3]

Bolivia.—NL Baroid brought a new barite-grinding plant onstream in 1978.[4]

Canada.—In February 1978, flooding closed the Walton barite mine at Pembroke, Nova Scotia. Barite mining had been conducted at the Walton mine since 1941 and the ore body had essentially been exhausted. No plans were announced to dewater the mine and resume operations.[5]

In Newfoundland, ASARCO Incorporated, and Price Co., the joint owners of the Buchans zinc-lead-copper mine at Red Indian Lake, were phasing out mining operations. The high-grade massive sulfide ore body averaged 22% barite which had not been recovered. Approximately 500,000 tons of recoverable barite were estimated to be in the tailing pond and additional barite is likely present in Red Indian Lake where tailings had been dumped in the early days of the operation.[6] It is probable that the mill will be converted to the mine's tailings to recover barites.[7]

Germany, Federal Republic of.—West German barite output declined in 1978 owing to the closure of "Sachtleben" Bergbau GmbH's Meggen mine in 1977. The Meggen mine had produced a total of 7.2 million tons of barite over its 72-year lifespan. The Federal Republic of Germany had seven remaining barite mines most of which were old, high-cost operations.[8]

India.—Over 90% of India's barite output came from the mining areas of the Cuddapah, Kurnool, Anantpur, Nellare, and Khaman districts of Andra Pradesh; the nation's major barite reserves were also located in these districts. Total measured and indicated barite reserves in India were estimated at about 180 million short tons; 60 million tons were measured reserves. Inferred reserves have been estimated at another 90 million tons of ore containing 86% to 90% barium sulfate, with a specific gravity of 3.8 to 4.0.

In 1978, the Indian Government, through its Minerals and Metals Trading Corp. (MMTC), set a minimum selling price for drilling-mud-grade ground barite of $57 per metric ton, f.o.b. India, and the minimum for lump material at $37 per metric ton.[9] The Indian Government introduced an export duty of 50 Rupees per metric ton of barite, effective September 4, 1978. Individual mine owners were restricted from selling more than 20% of their lump material exports to grinding plants in the nations of the Persian Gulf.[10]

Ireland.—Milchem (United States) reopened the Lady's Well barite mine near Clonakilty, County Cork, in early 1979.[11] The mine was dewatered in 1975 and a diamond-drilling program was completed in January 1978. The success of the drilling program prompted the mine's reopening with a planned annual capacity of 50,000 tons of barite. Milchem also extracted barite from the tailings of Northgate Exploration Ltd.'s lead-zinc mine at Tynagh, County Galway. Dresser Minerals operation at Silvermines, County Tipperary, continued to be Ireland's largest barite producer. IMCO operated the Glencarbury Barytes mine at Ben Bulben, County Sligo.

Liberia.—In 1978, Seinevin Mining Co., a firm entirely owned by Liberians, signed a concession agreement to mine barite in Gibi territory.

Nigeria.—NL Baroid began production in its new grinding plant to serve the Nigerian oil industry and other oil producing nations on the Gulf of Guinea.

Saudi Arabia.—In 1978, NL Baroid started up a new barite grinding plant near Dhahran in eastern Saudi Arabia.

Thailand.—In 1978, barite became Thailand's third most important mineral product, after tin and tungsten. Total barite production in 1979 reached an alltime high of 417,000 tons, 37.6% greater than the output of 1978 and more than three times the 1977 production level. About 20 barite mines were operated in Thailand; major producing areas were Chinag Mai, Nakhan Si Thammarat, Loei Songkhla, and Tak. Barite grinding mills were operated by Jalaprathan Cement Co., Ltd., Sobhu Thailand Co., Ltd., and Thailand Barite Co., Ltd. (a subsidiary of Dresser Minerals).

Turkey.—Early in 1978, Bostas Barytes Industry and Trading Co., Ltd., brought its new 120,000-ton-per-year barite grinding plant onstream at Antalya. Turkish grinding capacity has increased substantially since the Government ban on the export of raw barite which was instituted in late 1974. Seven companies had an estimated annual barite grinding capacity of 550,000

Table 13.—Barite: World production, by country

(Thousand short tons)

Country[1]	1976	1977	1978[p]	1979[e]
North America:				
Canada	111	129	97	[2]74
Guatemala	--	[e]1	1	4
Mexico	298	298	255	300
United States[3]	1,234	1,494	2,112	[p]1,987
South America:				
Argentina	45	34	36	40
Brazil	[r]35	55	119	120
Chile	[r]23	72	201	200
Colombia	4	4	4	4
Peru	365	479	399	480
Europe:				
Austria	(4)	(4)	(4)	--
Czechoslovakia[e]	8	8	8	8
France	165	243	248	250
German Democratic Republic[e]	34	34	39	40
Germany, Federal Republic of	289	293	186	200
Greece[5]	48	43	49	[2]53
Ireland	356	411	385	400
Italy	197	165	261	[2]237
Poland	89	98	100	100
Portugal	[r]1	1	1	1
Romania	[r] [e]94	[r] [e]94	96	97
Spain	[r] [e]102	92	[e]88	100
U.S.S.R.[e]	440	[r]500	520	550
United Kingdom	55	55	60	60
Yugoslavia	62	58	58	55
Africa:				
Algeria	83	53	80	100
Egypt	(4)	(4)	1	1
Kenya	[e](4)	(4)	(4)	(4)
Morocco	[r]142	164	195	[2]254
South Africa, Republic of	2	3	3	[2]3
Swaziland	(4)	--	--	--
Tunisia	26	18	18	18
Asia:				
Afghanistan[6]	6	[e]6	14	[2]3
Burma	[r]17	18	39	40
China, mainland[e]	[r]330	[r]385	440	550
India	215	347	387	400
Iran	254	204	220	NA
Japan	59	62	82	80
Korea, North[e]	130	130	120	120
Korea, Republic of	5	3	2	2
Malaysia	7	12	6	10
Pakistan	10	19	22	34
Philippines	4	6	6	6
Thailand	167	130	303	[2]417
Turkey	208	158	238	250
Oceania: Australia	[r]16	13	12	[2]12
Total	[r]5,736	6,392	7,511	7,610

[e]Estimate. [p]Preliminary. [r]Revised. NA Not available.

[1] In addition to the countries listed, Bulgaria and Southern Rhodesia also produce barite, but available information is inadequate to make reliable estimates of output levels.

[2] Reported figure.

[3] Sold or used by producers.

[4] Less than 1/2 unit.

[5] Barite concentrates.

[6] Year beginning March 21 of that stated.

tons in 1979.

United Kingdom.—Dresser Minerals acquired two grinding plants, one at Aberdeen, Scotland, and the other at Surwick, Shetland Islands.

Yugoslavia.—The Government plans to begin development of an opencast barite mine on Mount Bobija near Ljubovija in early 1980. A production level of 165,000 tons per year of ore yielding 60,000 tons of barite is anticipated when the operation is commissioned in 1983.

TECHNOLOGY

Industrial Minerals published an excellent summary[12] of the technology and world production of industrial minerals utilized in drilling oil and natural gas production and exploration wells; the various minerals, their uses, and markets were included.

A U.S. Geological Survey report[13] concluded that there may be economic resources of barite in the proposed 98-square-mile Jarbridge Wilderness Area in Elko County, Nev. Barite had been mined in 1957 at the Wildcat mine, a few hundred feet southeast of the study area, and there were several prospects in the southeastern part of the area. The report delineated 90,000 tons of resources averaging 90% barite and indicated that additional exploration could reveal significant ore-grade material in the proposed wilderness area.

The Bureau of Mines initiated a project to devise new methods for recovering barite from tailings at old mining or milling operations. This material represents a significant, largely unexploited barite resource. The project, being conducted at the Bureau's Tuscaloosa (Ala.) Research Center, also examined the improvement of current beneficiation techniques.

The Bureau's Reno (Nev.) Research Center was developing new methods to enhance recovery of rare earths and a marketable barite byproduct from bastnäsite ores. The ore used for developing the new methods was taken from Molybdenum Corp. of America's mine in Mountain Pass, Calif. Barite, which makes up about 25 weight-percent of the ore, is not recovered by Molybdenum Corp. at the Mountain Pass facility.

A barite heavy media system developed by the Bureau of Mines for separating nonferrous automobile scrap began operation in 1978 at Prolerized Schiabo New Co. in Jersey City, N.J. It was a more sophisticated industrial version of the Bureau's experimental unit at the Salt Lake City (Utah) Research Center. The float product comprised 99% pure aluminum metal; the sink product, after passing through a magnetic-separation mode, consisted principally of copper, brass, die-cast zinc, lead, and stainless steel.

IMCO developed a method for treating flotation barite to make it a more desirable drilling-mud material.[14] Treatment of flotation barite for use as a drilling mud was necessary because reagents used in the flotation process remain on the minus 200-mesh barite product and cause foaming of the drilling fluid. IMCO's treatment uses an indirect-fired rotary dryer to remove the reagents from the flotation barite. In 1978, a production-sized pilot plant was built at facilities of Avon Mineracao e Industria in Araxa, Minas Gerais, Brazil, where barite is recovered as a byproduct of niobium-columbium extraction. IMCO was designing and installing similar units in Nevada and Mexico in 1979.

Shell International Chemical Co., Ltd. developed a family of propylene-based, mineral impregnated fibers.[15] Mineral additives, including barium sulfate, in the branched propylene fibers impart desirable mineral properties to the fibers. Potential applications include building products (as a substitute for asbestos), filters, cable insulation, and battery-plate separators.

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[1] Physical scientist, Section of Nonmetallic Minerals.

[2] Haines, S. K., and R. G. Miller. Barite-A Statistical Summary. BuMines IC 8763, 1978, 25 pp.

[3] Costelli, A. V. Barite-U.S. Producer Prices Steady While Import Prices Rise. Eng. and Min. J., v. 180, No. 3, March 1979, pp. 120-121.

[4] Work cited in footnote 2.

[5] Canadian Mining Journal. Two N.S. (Nova Scotia) Mines Shut. V. 99, No. 4, April 1978, p. 12.

[6] Allman, N. J. Output Declines at Asarco's Buchans Unit. Northern Miner, v. 63, No. 47, Feb. 2, 1978, p. 1.

[7] Mining Journal (United Kingdom). Barytes at Buchans? V. 292, No. 7494, Apr. 6, 1979, p. 271.

[8] U.S. Embassy, Dusseldorf, Federal Republic of Germany. State Department Airgram A-53, Apr. 25, 1978.

[9] Industrial Minerals. Barytes Floor Price. No. 129, June 1978, p. 10.

[10] Costelli, A. V. Barite-Prices Increase While Output Holds Steady. Eng. and Min. J., v. 181, No. 3, March 1980, pp. 88, 91.

[11] Work cited in footnote 9.

[12] Harben, P. W. (ed.). Raw Materials for the Oil Well Drilling Industry. An "Industrial Minerals" Consumer Survey, London, 1978, 144 pp.

[13] Engineering and Mining Journal. Ongoing Projects. V. 179, No. 7, July 1978, p. 151.

[14] Cornell, N. Roasting to Recover Flotation-Barite Waste Product. Eng. and Min. J., v. 179, No. 9, September 1978, pp. 208, 211.

[15] Chemical Week. Technology Newsletter. V. 123, No. 22, Nov. 29, 1978, p. 48.

Bauxite and Alumina

By Luke H. Baumgardner[1] and Ruth A. Hough[2]

A sharp decline in bauxite production in 1978 in Australia, the leading world supplier, was only partially offset by increases in Guinea and Jamaica, and total world mine output was lower than in 1977. Production increased markedly in 1979 to a new world record. World production of alumina in 1978 was slightly higher than in 1977 and also increased in 1979. Domestic production of bauxite and alumina in 1978-79, as in past years, showed little change.

Jamaica, Guinea, and Suriname remained the principal sources of bauxite imported into the United States in 1978-79. Brazil became a new supplier of bauxite to the United States in the fourth quarter of 1979. Also during 1979, a decline in imports of calcined refractory-grade bauxite from Guyana caused some concern among domestic consumers. Australia, Jamaica, and Suriname were the principal suppliers of alumina imported by the United States.

Note: All quantities in this chapter are given in metric tons unless otherwise indicated. Metric tons can be converted to long tons by multiplying by 0.984207 or to short tons by multiplying by 1.10231.

Legislation and Government Programs.—General Services Administration stockpiles of bauxite remained virtually unchanged throughout 1978-79, except for the shipment in 1978 of metal-grade bauxite which had been sold previously. Inventories at the end of 1979 included about 14.4 million metric tons of metal-grade bauxite, and 177,000 tons of calcined refractory-grade bauxite. Stockpile goals were 0.5 million tons of metal-grade bauxite, 2.1 million tons of refractory-grade bauxite, and 10.5 million tons of alumina. There were no Government stocks of alumina.

The Tokyo Round of international trade negotiations, which resulted in agreements to reduce certain tariffs, did not affect the duties on U.S. imports of bauxite and alumina which have been suspended since 1971.

Table 1.—Salient bauxite statistics

(Thousand metric tons and thousand dollars)

	1975	1976	1977	1978	1979
United States:					
Production: Crude ore (dry equivalent)	1,801	1,989	2,013	1,669	1,821
Value	$25,083	$26,645	[r]$27,555	$23,185	$24,875
Exports (as shipped)	20	15	26	13	15
Imports for consumption[1]	11,714	12,749	12,989	13,847	13,780
Consumption (dry equivalent)	12,587	14,039	14,528	14,738	15,697
World: Production	74,791	[r]77,463	[r]82,374	81,029	86,814

[r]Revised.

[1]Excludes calcined bauxite. Includes bauxite imported into the Virgin Islands.

DOMESTIC PRODUCTION

Bauxite mines were operated in Arkansas in 1978-79 by the Aluminum Co. of America (Alcoa), American Cyanamid Co., and Reynolds Mining Corp. in Saline County and by Reynolds in Pulaski County. All production has been from open pit mines since Reynolds closed the last domestic underground bauxite mine in 1976. In both 1978 and 1979 American Cyanamid produced calcined bauxite at its Benton plant, and Porocel

Corp. (subsidiary of Engelhard Minerals & Chemicals Corp.) produced activated bauxite at its local Berger plant.

Five companies mined bauxite in Alabama in 1978-79. Mines located in the Eufala district, Barbour and Henry Counties, were operated by Abbeville Lime Co., A. P. Green Refractories Co. (United States Gypsum Co.), Harbison-Walker Refractories Co. (Dresser Industries, Inc.), Mullite Co. of America (C-E Minerals Div. of Combustion Engineering Inc.), and Wilson-Snead Mining Co. (NL Industries, Inc.). Late in 1978 Wilson-Snead was purchased by Didier-Taylor Refractories Corp., and operations at the mines and plant were continued by the new owner. Abbeville Lime Co. went out of business in January 1979. Dried and calcined bauxite was produced by A. P. Green, Harbison-Walker, and Wilson-Snead (became Didier-Taylor).

In Sumter County, Ga., bauxite was mined and dried or calcined by American Cyanamid and Mullite Co. of America near Andersonville.

The production of alumina (excluding aluminates) at the eight Bayer-process alumina plants in the United States and the one plant in the U.S. Virgin Islands declined slightly in 1979. The total production included calcined alumina, commercial alumina trihydrate, and tabular, activated, and other alumina.

Calcined alumina shipments to primary aluminum plants totaled an estimated 5.4 million metric tons, or 90% of the calcined equivalent of total shipments in 1978 and 5.8 million tons or 89% of shipments in 1979. The chemical industry, including producers of aluminum fluoride fluxes for aluminum plants, received over half of the remaining tonnage, largely as hydrate. Other shipments of alumina went mainly to producers of abrasives, ceramics, and refractories.

Table 2.—Mine production of bauxite and shipments from mines and processing plants to consumers in the United States

(Thousand metric tons and thousand dollars)

State and year	Mine production			Shipments from mines and processing plants to consumers[1]		
	Crude	Dry equivalent	Value[2]	As shipped	Dry equivalent	Value[2]
1977:						
Alabama and Georgia	387	310	[r]2,704	105	188	[r]8,151
Arkansas	2,048	1,703	24,851	1,964	1,684	26,532
Total[3]	2,436	2,013	[r]27,555	2,069	1,873	[r]34,683
1978:						
Alabama and Georgia	288	223	2,083	133	180	8,007
Arkansas	1,778	1,446	21,103	1,734	1,483	24,230
Total[3]	2,066	1,669	23,185	1,866	1,663	32,237
1979:						
Alabama and Georgia	501	391	4,320	222	286	14,821
Arkansas	1,685	1,430	20,555	1,695	1,442	24,600
Total	2,186	1,821	24,875	1,917	1,728	39,421

[r] Revised.

[1] May exclude some bauxite mixed in clay products.

[2] Computed from values assigned by producers and from estimates of the Bureau of Mines.

[3] Data may not add to totals shown because of independent rounding.

Table 3.—Recovery of dried, calcined, and activated bauxite in the United States

(Thousand metric tons)

Year	Crude ore treated	Total processed bauxite recovered[1]	
		As recovered	Dry equivalent
1977	419	169	234
1978	379	154	236
1979	466	235	336

[1] Dried, calcined, and activated bauxite. May exclude some bauxite mixed in clay products.

Table 4.—Percent of domestic bauxite shipments, by silica content

SiO_2 (percent)	1975	1976	1977	1978	1979
Less than 8	4	6	2	2	1
From 8 to 15	62	50	54	55	55
More than 15	34	44	44	43	44

Table 5.—Production and shipments of alumina in the United States

(Thousand metric tons)

Year	Calcined alumina	Other alumina[1]	Total[3]	
			As produced or shipped[2]	Calcined equivalent
Production:				
1975	4,738	566	5,304	5,135
1976[e]	5,400	600	6,000	5,800
1977[e]	5,580	660	6,230	6,030
1978[e]	5,550	580	6,130	5,960
1979[e]	5,950	700	6,650	6,450
Shipments:				
1975	4,747	570	5,316	5,145
1976[e]	5,400	600	6,000	5,800
1977[e]	5,510	660	6,160	5,960
1978[e]	5,620	580	6,200	6,030
1979[e]	5,970	710	6,680	6,480

[e] Estimate.

[1] Trihydrate, activated, tabular, and other aluminas. Excludes calcium and sodium aluminates.

[2] Includes only the end product if one type of alumina was produced and used to make another type of alumina.

[3] Data do not add to total shown because of independent rounding.

Table 6.—Capacities of domestic alumina plants[1]

(Thousand metric tons per year)

Company and plant	Capacity Dec. 31, 1978	Capacity Dec. 31, 1979
Aluminum Co. of America:		
Bauxite, Ark	340	325
Mobile, Ala	900	800
Point Comfort, Tex	1,210	1,325
Total	2,450	2,450
Martin Marietta Aluminum, Inc.: St. Croix, V.I	508	508
Kaiser Aluminum & Chemical Corp.:		
Baton Rouge, La	930	930
Gramercy, La	726	726
Total	1,656	1,656
Ormet Corp.: Burnside, La	544	544
Reynolds Metals Co.:		
Hurricane Creek, Ark	650	650
Corpus Christi, Tex	1,400	1,400
Total	2,050	2,050
Grand total	7,208	7,208

[1] Capacity may vary depending upon the bauxite used.

CONSUMPTION AND USES

The amount of bauxite refined to various forms of alumina during the 1977-79 period was close to 93% of total bauxite consumption for each year. The ratio between bauxite consumed and alumina produced indicated that an average of approximately 2.26 metric tons (dry basis) of bauxite was required to produce 1 metric ton (calcined basis) of alumina. One of the two alumina plants in Arkansas processed only locally mined bauxite while the other used a blend of domestic and foreign ores. The other seven alumina plants used only imported bauxite.

Approximately 27% of the total bauxite consumed by the refractories industry in 1978 came from domestic mines. This increased to 32% in 1979. A small but known quantity of bauxite blended with clay was not included in consumption figures.

Data on consumption of bauxite for abrasive use, shown in table 7, includes bauxite that is consumed in Canada to make intermediate abrasive products which are consumed in the United States.

Consumption of bauxite by the chemical industry recorded significant gains in both 1978 and 1979. Approximately 80% of the bauxite consumed by the chemical industry in 1978-79 was imported. According to the Bureau of the Census, commercial aluminum sulfate production in the United States increased in 1978.

An estimated 70,000 metric tons of bauxite was consumed in 1978-79 by the cement, oil, and gas industries and municipal waterworks.

In 1978, 31 primary aluminum plants in the United States consumed 8,303,000 metric tons of calcined alumina, an increase of 5% over consumption in 1977. In 1979, 32 aluminum smelters used 8,793,000 tons of calcined alumina, an additional increase of about 6%. Alumina consumption data for other uses were not available. A significant quantity was used to make aluminum fluoride and synthetic cryolite, which is also used in the production of primary aluminum.

Table 7.—Bauxite consumed in the United States by industry

(Thousand metric tons, dry equivalent)

Year and industry	Domestic	Foreign	Total[1]
1978:			
Alumina	1,449	12,144	13,593
Abrasive[2]	--	310	310
Chemical	[3]75	[3]216	221
Refractory	146	398	544
Other	W	W	70
Total[1] [3]	1,671	13,068	14,738
1979:			
Alumina	1,426	13,098	14,524
Abrasive[2]	--	327	327
Chemical	[3]70	[3]255	256
Refractory	169	351	520
Other	W	W	70
Total[1] [3]	1,665	14,032	15,697

W Withheld to avoid disclosing company proprietary data; included with "Chemical."

[1] Data may not add to totals shown because of independent rounding.

[2] Includes consumption by Canadian abrasive industry.

[3] Includes other uses.

Table 8.—Crude and processed bauxite consumed in the United States

(Thousand metric tons, dry equivalent)

Type	Domestic origin	Foreign origin	Total[1]
1978:			
Crude and dried	1,460	12,358	13,818
Calcined and activated	211	709	920
Total[1]	1,671	13,068	14,738
1979:			
Crude and dried	1,437	13,354	14,792
Calcined and activated	228	677	905
Total[1]	1,665	14,032	15,697

[1] Data may not add to totals shown because of independent rounding.

Table 9.—Production and shipments of selected aluminum salts in the United States

(Thousand metric tons and thousand dollars)

Item	Number of producing plants	Production	Total shipments including interplant transfers	
			Quantity	Value
1977:				
Aluminum sulfate:				
Commercial and municipal (17% Al_2O_3)	66	1,138	1,052	96,792
Iron-free (17% Al_2O_3)	15	112	106	7,847
Aluminum chloride:				
Liquid and crystal (32° Bé)	4	19	W	W
Anhydrous (100% $AlCl_3$)	6	41	25	19,338
Aluminum fluoride, technical	5	135	136	75,373
Aluminum hydroxide, trihydrate (100% $Al_2O_3 \cdot 3H_2O$)	6	W	W	W
Other inorganic aluminum compounds[1]	XX	XX	XX	44,646
1978:				
Aluminum sulfate:				
Commercial and municipal (17% Al_2O_3)	66	1,187	1,104	108,840
Iron-free (17% Al_2O_3)	16	125	111	7,981
Aluminum chloride:				
Liquid and crystal (32° Bé)	4	18	W	W
Anhydrous (100% $AlCl_3$)	5	62	28	19,877
Aluminum fluoride, technical	5	138	139	80,954
Aluminum hydroxide, trihydrate (100% $Al_2O_3 \cdot 3H_2O$)	6	W	W	W
Other inorganic aluminum compounds[1]	XX	XX	XX	42,450

W Withheld to avoid disclosing company proprietary data. XX Not applicable.

[1] Includes aluminum chloride, liquid and crystal; aluminum hydroxide; sodium aluminate; light aluminum hydroxide; cryolite and alums.

Source: Data are based upon Bureau of the Census report Form MA-28E.1, Annual Report on Shipments and Production of Inorganic Chemicals.

STOCKS

Total bauxite inventories in the United States remained about the same in 1978-79 as they were at yearend 1977. Producers and processors stocks and Government stockpiles were drawn down in 1978 and remained below the 1977 level through 1979. By contrast, consumers inventories increased in 1978-79.

Government-owned bauxite stockpiles contained 9,001,000 metric tons of Jamaica-type ore and 5,385,000 tons of Suriname-type ore through the end of 1979, unchanged from 1977 quantities. Approximately 426,000 tons of Suriname-type bauxite, which had been sold previously, was shipped from the stockpile in 1978. Yearend Government stockpiles of calcined refractory-grade bauxite were unchanged during 1978-79 although the reported total was revised slightly to 177,401 tons.

Inventories of calcined and other forms of alumina at plants producing alumina and primary aluminum metal decreased in 1978 to 1,424,000 metric tons and remained virtually unchanged in 1979. No stocks of alumina, except as aluminum oxide abrasive grain and fused crude, were held in Government stockpiles in 1978-79.

Table 10.—Stocks of bauxite in the United States[1]

(Thousand metric tons, dry equivalent)

Sector	Dec. 31, 1977	Dec. 31, 1978	Dec. 31, 1979
Producers and processors	r685	556	607
Consumers	r7,284	7,806	7,982
Government	15,087	14,661	14,661
Total	r23,056	23,023	23,250

r Revised.

[1] Domestic and foreign bauxite; crude, dried, calcined, activated; all grades.

Table 11.—Stocks of alumina in the United States[1]

(Thousand metric tons, calcined equivalent)

Sector	Dec. 31, 1977[r]	Dec. 31, 1978	Dec. 31, 1979
Producers[e]	227	165	143
Primary aluminum plants	1,291	1,259	1,278
Total	[2]1,519	1,424	1,421

[e] Estimate. [r] Revised.

[1] Excludes consumers stocks other than those at primary aluminum plants.

[2] Data do not add to total shown because of independent rounding.

PRICES

Prices on most of the bauxite and alumina produced throughout the world are not quoted because the large tonnages used by the aluminum industry are usually obtained from affiliated companies or purchased under long-term negotiated contracts.

The Bureau of Mines estimated the average value of crude domestic shipments, f.o.b. mine or plant, at $11.10 per metric ton in 1978 and $11.50 per ton in 1979. The average value of shipments of domestic calcined bauxite was estimated at $66 per ton in 1978 and $85 per ton in 1979. The Bureau's estimates of the value of shipments were based on incomplete data supplied by producers. Bauxite values among producers varied widely because of differences in grade.

The value of imported bauxite consumed at alumina plants in the United States was believed to have increased in 1978-79, but sufficient company data were not available to determine an average value. Engineering and Mining Journal published the following prices on super-calcined, refractory-grade bauxite imported from Guyana, car lots, per metric ton:

	January 1978-July 1979	August 1979-December 1979
F.o.b.		
Baltimore, Md	$138.42	$166.78
F.o.b.		
Mobile, Ala	138.42	166.78

The estimated average value of domestic shipments of calcined alumina was $164 per metric ton in 1978 and $173 per ton in 1979. The average value of imported alumina (including small quantities of hydrate), as reported by the Bureau of the Census, was $148 per ton at port of shipment (f.a.s.) and $157 per ton at U.S. ports (c.i.f.) in 1978 and $162 per ton (f.a.s.) and $172 per ton (c.i.f.) in 1979.

Table 12.—Average value of U.S. imports of crude and dried bauxite[1]

(Per metric ton)

Country	1978		1979	
	Port of shipment (f.a.s.)	Delivered to U.S. ports (c.i.f.)	Port of shipment (f.a.s.)	Delivered to U.S. ports (c.i.f.)
To U.S. mainland:				
Brazil	--	--	$22.51	$31.36
Dominican Republic	$30.39	$33.74	32.75	35.91
Guinea	21.58	28.92	21.46	28.13
Guyana	21.58	32.62	28.07	42.47
Haiti	24.02	27.62	26.33	31.36
Jamaica	30.91	33.58	28.10	31.29
Sierra Leone	12.80	21.66	15.37	25.16
Suriname	22.70	31.41	24.82	34.98
Other	33.77	40.23	18.45	44.28
To U.S. Virgin Islands:				
Guinea	13.28	19.72	13.18	19.66
Weighted average	26.34	31.26	25.46	30.70

[1] Computed from quantity and value data reported to U.S. customs service and compiled by the Bureau of the Census, U.S. Department of Commerce. Not adjusted for moisture content of bauxite or differences in methods used by importers to determine value of individual shipments.

Table 13.—Market quotations on alumina and aluminum compounds

(Per metric ton, in bags, carlots, freight equalized)

Compound	Jan. 2, 1978	Jan. 1, 1979	Dec. 31, 1979
Alumina, calcined	$228.18	$228.18	$228.18
Alumina, hydrated, heavy	143.30	143.30	143.30
Alumina, activated, granular, works	352.74	352.74	352.74
Aluminum sulfate, commercial, ground (17% Al_2O_3)	142.20	151.02	160.94
Aluminum sulfate, iron-free, dry (17% Al_2O_3)	154.32	220.46	237.00

Source: Chemical Marketing Reporter.

FOREIGN TRADE

United States exports of bauxite, including calcined bauxite, totaled 23,000 metric tons valued at $2.8 million in 1978 and 24,000 tons valued at $4.7 million in 1979. Canada received 67% of the total in 1978. Virtually all of the exports in 1979 went to either Canada (48%) or Mexico (49%).

Total exports of alumina included shipments from the alumina plant in the U.S. Virgin Islands of 239,000 tons to the U.S.S.R. and 93,000 tons to Norway in 1978, and 153,000 tons to Norway, 69,000 tons to the U.S.S.R., 24,000 tons to Ghana, and 18,000 tons to Venezuela in 1979. Most of the other exports were shipments from domestic alumina plants on the gulf coast to aluminum plants in Canada, Ghana, and Mexico in 1978, and Canada, Mexico, and Venezuela in 1979. Exports classified as "other aluminum compounds" declined in 1978 but increased in 1979. Much of the tonnage in this category was believed to be aluminum fluoride and synthetic cryolite shipped to other countries for use as a flux in making primary aluminum.

Imports of crude, partially dried, and dried bauxite into the United States and the U.S. Virgin Islands increased in 1978 and remained virtually the same in 1979. The first large shipments of bauxite from the new Trombetas bauxite project in the Amazon Basin of Brazil were recorded in the fourth quarter of 1979. Jamaica continued to provide almost half of the total in both years.

Calcined bauxite imports increased in

Table 14.—U.S. exports of alumina,[1] by country

(Thousand metric tons and thousand dollars)

Country	1977		1978		1979	
	Quantity	Value	Quantity	Value	Quantity	Value
Argentina	1	468	1	387	3	1,754
Australia	2	757	1	641	3	1,099
Belgium-Luxembourg	1	872	(2)	366	(2)	328
Brazil	5	1,588	1	766	1	863
Canada	73	17,929	186	41,456	185	44,954
France	4	r1,852	5	2,723	4	2,558
Germany, Federal Republic of	r3	r3,680	4	4,081	6	5,867
Ghana	215	29,183	134	17,966	94	14,295
Japan	2	2,765	2	4,627	3	4,592
Mexico	123	r20,917	121	21,994	131	25,691
Netherlands	1	818	2	1,392	2	1,391
Norway	35	r4,254	93	12,231	204	30,042
Poland	(2)	51	(2)	36	(2)	80
Sweden	55	8,027	28	4,749	2	1,585
U.S.S.R.	324	38,208	239	31,120	70	8,462
United Kingdom	4	2,198	5	3,070	5	3,547
Venezuela	2	r1,362	46	8,245	128	26,915
Other	r7	r6,086	10	6,600	8	8,050
Total	857	r141,015	878	162,400	849	182,068

rRevised.

[1] Includes exports of aluminum hydroxide: 1977—33,800 tons; 1978—44,100 tons; 1979—36,800 tons. Also includes alumina exported from the U.S. Virgin Islands to foreign countries: 1977—330,000 tons; 1978—332,000 tons; 1979—264,000 tons.

[2] Less than 1/2 unit.

Table 15.—U.S. imports for consumption of bauxite, crude and dried, by country[1]

(Thousand metric tons)

Country	1977	1978	1979
Australia	(2)	19	--
Brazil	--	--	168
Dominican Republic[3]	583	628	551
Greece	57	3	10
Guinea	3,030	3,363	3,924
Guyana	380	419	425
Haiti	587	588	572
Jamaica[3]	6,354	6,448	6,469
Sierra Leone	80	107	141
Suriname	1,918	2,259	1,520
Trinidad and Tobago[4]	--	13	--
Other	(2)	--	--
Total	12,989	13,847	13,780

[1] Includes bauxite imported into the U.S. Virgin Islands from foreign countries: 1977—872,000 tons; 1978—1,033,000 tons; 1979—1,051,000 tons.

[2] Less than 1/2 unit.

[3] Dry equivalent of shipments to the United States.

[4] Shipments probably originated in Guyana or Suriname.

Note: Total U.S. imports of crude and dried bauxite (including U.S. Virgin Islands) as reported by U.S. Bureau of the Census were: 1977—14,245,746 tons, 1978—15,069,625 tons, 1979—15,291,176 tons.

Table 16.—U.S. imports for consumption of bauxite (calcined), by country[1]

(Thousand metric tons and thousand dollars)

Country	1977		1978		1979	
	Quantity	Value[1]	Quantity	Value[1]	Quantity	Value[1]
Australia	--	--	--	--	8	241
China, mainland	--	--	--	--	24	2,513
Guyana	220	21,635	220	28,609	190	27,006
Suriname	21	1,755	31	2,569	50	4,530
Other	1	54	1	292	(2)	93
Total	242	23,444	252	31,470	267	34,383

[1] Value at foreign port of shipment as reported to U.S. Customs Service.

[2] Less than 1/2 unit.

Table 17.—U.S. imports for consumption of alumina[1] by country

(Thousand metric tons and thousand dollars)

Country	1977		1978		1979	
	Quantity	Value[2]	Quantity	Value[2]	Quantity	Value[2]
Australia	2,590	318,760	2,879	382,017	2,938	433,382
Canada	21	4,260	28	6,327	23	5,704
France	8	13,539	12	19,753	12	21,350
Germany, Federal Republic of	25	6,995	7	4,425	11	8,158
Guyana	54	6,610	30	3,777	18	1,539
Jamaica	629	106,889	628	113,313	587	106,120
Japan	51	6,813	(3)	274	1	1,080
Suriname	382	47,750	382	58,650	239	41,245
Other	(3)	797	1	1,276	8	1,844
Total	3,760	512,413	3,967	589,812	3,837	620,422

[1] Includes aluminum hydroxide; excludes shipments from the U.S. Virgin Islands to the United States: 1977—95,129 tons ($17,492,940); 1978—123,353 tons ($22,619,924); 1979—Not available.

[2] Value at foreign port of shipment as reported to U.S. Customs Service.

[3] Less than 1/2 unit.

both 1978 and 1979. Most of these imports were refractory-grade bauxite from Guyana. Calcined bauxite was imported into Canada for manufacture into crude fused aluminum oxide, much of which was subsequently exported to the United States for use in abrasive and refractory products. In both 1978 and 1979, this bauxite was imported into Canada principally from Suriname but also from Australia, Guinea, and other countries.

Alumina from Australia, largely to aluminum plants in the Pacific Northwest, continued to provide most of the total imports of alumina in 1978-79.

WORLD REVIEW

World bauxite production from the 28 contributing countries rose significantly to 87.7 million metric tons in 1979 after a reduced output of 81.0 million tons in 1978. Australia was, as it has been since 1971, the leading producer, followed in both 1978 and 1979 by Guinea and Jamaica. Among the major producers, Brazil, Greece, Yugoslavia, Malaysia, and Australia all increased bauxite production by more than 10% from 1978 to 1979.

Output of the 25 alumina-producing countries totaled 29.6 million tons in 1978 and 30.9 million tons in 1979, relatively small gains over world production in 1977. Only three countries, Yugoslavia, Taiwan, and Turkey, achieved alumina production gains of 10% or more in 1979 over 1978. The majority of countries had minor changes in alumina output from 1978 to 1979. However, Canada and Guyana each registered a sharp drop in tonnage for 1979.

Australia.—Australia remained the world leader in the production of bauxite and alumina. Three companies, Alcoa of Australia (W.A.) Ltd., Comalco Ltd., and Nabalco Pty. Ltd., accounted for virtually all of the bauxite and alumina produced in Australia during 1978-79.

Bauxite from Alcoa's Jarrahdale, Del Park, and Huntly mines was refined at the company's Kwinana and Pinjarra alumina plants located south of Perth in Western Australia. The combined alumina capacity of the two plants was 3.6 million tons per year. In October 1978, Alcoa received approval from the state to build a new alumina plant at Wagerup, about 120 kilometers south of Perth. Bauxite ore was to be supplied from a new mine in the Darling Range. Construction of this 500,000-ton-per-year refinery commenced in 1979, and alumina production was scheduled to begin in 1982. Ultimate expansion to 2-million-ton-per-year capacity, a fourfold increase, was considered possible.

Reynolds Metals Co. announced the formation of a partnership, Worsley Alumina Pty. Ltd., for an $A1,000 million bauxite-alumina project. The alumina plant was to be located about 130 kilometers southeast of Perth, Western Australia. Participants include Reynolds Australia Alumina Ltd. (40%), Shell Co. of Australia (30%), and Broken Hill Proprietary Co. Ltd. (20%). An Australian consortium of three Japan-based companies, Kobe Steel Ltd., Nissho-Iwai Co. Ltd., and C. Itoh & Co. Ltd., holds the remaining 10%. Initial capacity will be 1 million tons of alumina per year, and the plant will be designed for expansion to 2 million tons at some future date. Production was expected to start in the second half of 1983. Bauxite will be supplied from the company's 200-million-ton Mt. Saddleback deposits northeast of the Worsley plant site.

In northern Western Australia, a major interest in the 235-million-ton Mitchell Plateau bauxite deposits was offered in mid-1979 to Conzinc Riotinto of Australia Ltd. (CRA) by Alumax Bauxite Corp. CRA agreed to purchase an initial 10% interest with a 12-month option to acquire an additional 42.5%. If the purchase option is exercised, CRA would have a controlling interest in the project.

After 14 years of progressive annual increases in bauxite production, Comalco's Weipa mines on Cape York Peninsula in Queensland recorded in 1978 an 18% drop in production to 8.23 million tons. Reduced output was attributed primarily to a downturn in world markets and, to a lesser degree, by a 3-week strike. For 1979, production of bauxite totaled 9.58 million tons, a 16% increase over 1978 production, but still below the record 10 million tons of 1977. Shipments of bauxite declined from 9.41 million tons in 1977 to 8.2 million tons in 1978. A 10% increase raised 1979 shipments to 8.99 million tons. Approximately half of the Weipa bauxite shipped during this period was processed at the Queensland Alumina Ltd. (QAL) plant at Gladstone. Abrasive-grade calcined bauxite produced was 211,000 and 248,000 tons in 1978 and 1979, respectively. Alumina production at Gladstone, the world's largest alumina refinery, totaled 2.215 million tons in 1978 and 2.43 million tons in 1979.

Nabalco, owned 70% by Swiss Aluminium Ltd. (Alusuisse) and 30% by Gove Alumina, Ltd., mined bauxite near Gove, Northern Territory, both for export and to supply Nabalco's Gove alumina plant. Bauxite production was about 4.9 million tons in 1978 and 5.0 million tons in 1979. Alumina production for 1978 and 1979 was 1.09 and 1.05 million tons, respectively. In the fourth quarter of 1979 the Gove plant was modified to produce sandy instead of floury alumina and plant capacity was increased to 1.1 million tons per year.

Brazil.—Bauxite production more than doubled from 1978 to 1979. The bauxite mined by Mineração Rio do Norte (MRN) in the Amazon Basin accounted for a major part of the increased output in 1979. MRN's first commercial shipments were made from the Port of Trombetas in the last quarter of 1979. The weighted average grade was reported to be 50.17% available Al_2O_3 and 3.82% reactive SiO_2. Production of bauxite was expected to exceed 2 million tons in 1980 and rise to the mine's rated capacity of 3.35 million tons per year by the end of 1982. Santa Patricia Mining Co. (a National Bulk Carriers subsidiary) was granted a bauxite mining concession in the Oriximina area near Trombetas in 1978. Companhia Vale do Rio Doce (CVRD) and Riofinex (a Rio Tinto Zinc subsidiary) announced they had deferred development of the Vera Cruz bauxite deposits in the Paragominas region.

Companhia Mineira de Aluminio (Alcominas) announced in 1979 that it would increase its Poços de Caldas alumina plant capacity by 63,500 tons per year to an annual capacity of 210,000 tons. Alcan Aluminio do Brasil SA also planned an increase in the annual capacity of its Saramenha alumina plant from 91,000 tons to 120,000 tons.

China, mainland.—A trial shipment of 16,500 tons of calcined refractory-grade bauxite was sent to several U.S. refractory companies in early 1979 (a shipment some years earlier had reportedly been unacceptable). The material was apparently found to be satisfactory by industry and orders for an additional 30,000 tons of refractory-grade bauxite were placed. The Chinese Government was reportedly interested in supplying U.S. markets with 100,000 metric tons annually, or about 25% of the U.S. demand. The Chinese Government reported a large new bauxite discovery in the southern area of Guangzi Zhuang Province and planned to build a 600,000-ton-per-year alumina refinery and associated reduction plant.

France.—Three alumina plants, located at Gardanne, Barasse, and Salindres, were owned and operated by Pechiney Ugine Kuhlmann (PUK). Pechiney and Alcan Aluminum Ltd. were studying the feasibility of testing their H-Plus dual-acid process for producing alumina from clay in a 50,000- to 100,000-ton-per-year plant.

Greece.—Aluminium de Grece SA, 70% owned by PUK, announced plans to increase its annual alumina capacity by 100,000 metric tons to a total of 600,000 tons at a reported cost of $100 million. The additional alumina was to be exported. Mine expansions, announced or in progress, were reported for Bauxite Parnasse, Eleusis Bauxite, and Elikon Bauxite.

Guinea.—Increased production by three mining companies made Guinea the second largest bauxite producer in the world in 1978-79. The largest producer was Guinea Bauxite Co. (CBG), jointly owned by the Government of Guinea (49%) and Halco (51%). The latter was a joint venture of Alcoa (27%), Alcan (27%), Martin Marietta (20%), PUK (10%), Vereinigte Aluminium-Werke AG (VAW) (10%), and Montecatini Edison SPA (6%). CBG produced approximately 8.1 million tons of bauxite in 1978 and an estimated 8.7 million tons in 1979 from its Sangaredi mine in the Boké region.

The Dabola mine near Kindia was operated by the Kindia Bauxite Office (OBK), a state-owned development assisted and financed by the Soviet Union. Estimated bauxite production in 1978 was 2.2 million tons and in 1979, 1.9 million tons. All bauxite from this mine was exported to the U.S.S.R.

Fria-Kimbo, the third operating bauxite mine, was owned jointly by the Government of Guinea (49%) and Frialco (51%). Frialco's partners included Noranda Mines Ltd. (38.5%), PUK (26.5%), British Aluminium Co., Ltd. (Baco) (10%), Alusuisse (10%), and VAW (5%). The entire mine output, 1.7 million tons in 1978 and 1.8 million tons in 1979, was refined to alumina in the company's Kimbo plant.

Alusuisse was contracted by Société Guinéo-Arabe D'Alumine et d'Aluminium (Alugui) to study the feasibility of building an alumina refinery and reduction plant near Boké to process bauxite from the Ayékoyé deposits. No firm plans were announced by the Alugui group which includes Guinea (50%) and Libya, Egypt, Kuwait, Saudi Arabia, and the United Arab Emirates. Exploration continued in other bauxite areas including Dabola, Kindia, Gaoual, Pata, and Labé.

Guyana.—A depressed bauxite and alumina market, the collapse of a conveyor at the Linden alumina plant, and a series of labor strikes combined to reduce 1978-79 production below the 1977 output. The Bauxite Industry Development Co. (Bidco), a state-owned holding company created to direct the mining, calcining, and refining operations at the facilities formerly owned by Alcan and Reynolds Metals subsidiaries, was reportedly successful in locating new markets. A 4-year contract to supply alumina to a new Brazilian primary aluminum plant was signed in 1978. Annual shipments of 88,000 tons were to be made from 1981 to 1985. A sales contract was signed in 1979 for the purchase of 30,000 tons of bauxite by the German Democratic Republic. The Guyana Government announced in mid-1978 that the U.S.S.R. would conduct a feasibility study to increase bauxite production by 600,000 tons per year.

Hungary.—Approximately 83% of the country's bauxite was produced from underground mines. The Deaki II mine in the Bakony Mountains near Nyirad, which opened late in 1977, continued to produce at a rate of about 200,000 tons per year. Other new deposits, including Bito II and Feryofo, were being developed by the state-owned Fejer County bauxite mining group in an attempt to achieve a 3.1- to 3.2-million-ton annual production target by the end of 1980.[3] Development of bauxite deposits associated with lignite beds at Nagyegyhaza was delayed by problems encountered in refining this ore by the Bayer process.

Ireland.—Financing arrangements for the 800,000-ton-per-year alumina plant at Aughinish Island, County Limerick, were completed in October 1978 and construction work on the plant continued through 1979. The plant will be operated by Aughinish Alumina Ltd., owned jointly by affiliates of Alcan (40%), Billiton B.V. (35%), and Anaconda Aluminum Co. (25%). The plant will use bauxite from Guinea and Brazil. Production was originally scheduled to begin in 1982, but construction has been delayed due to recurring differences between labor and management.

Jamaica.—To stimulate bauxite production, Jamaica announced in late 1979 a new reduced levy which was to be applied to ore production that exceeded a Government-determined reference quantity (approximately 85% of each company's rated mining capacity).

In 1977 Jamaica finalized agreements to purchase 51% of the mining assets of both Kaiser Bauxite Co. and Reynolds Jamaica Mine Ltd. All bauxite lands held by the two companies were to be purchased by the Government with a leaseback arrangement, assuring each company a 40-year supply of bauxite reserves. In September 1978 the Government agreed to purchase 7% of the bauxite and alumina production assets of Alcan Jamaica Ltd. All bauxite lands held by the company were to be purchased by the Government. In November 1979 Alcoa Minerals of Jamaica concluded an agreement to sell the Government a 6% interest in its mining and refining assets and 100% of its mineral lands. The new joint venture was called Jamalco. Alcan and Alcoa were granted leases on sufficient bauxite reserves to sustain operations. Agreements had not yet been signed by the end of 1979 with the two remaining bauxite-alumina companies, Revere Jamaica Alumina, Ltd., and Alumina Partners of Jamaica (Alpart). Alpart is a partnership between Reynolds (36.5%), Kaiser (36.5%), and Anaconda (27%). Revere shut down mining and alumina operations in August 1975 after failing to resolve its differences with the Government over the bauxite levy. In the fourth quarter of 1979 Revere was reported to have offered for sale its mining facility and 200,000-ton-per-year alumina plant.

Jamaica was active in developing new markets for its share of alumina production. In 1979, sales contracts were reportedly signed with Hungary, Algeria, Iraq, and Venezuela for delivery of 150,000 tons of alumina to each country over various time spans. A total of 250,000 tons is to be sold to the Soviet Union over a period of 5 years. A tentative plan was proposed to double the capacity of the Jamalco refinery at Woodside to provide alumina to three Norwegian companies, Norsk Hydro A/S, A/S Ardal og Sunndal Verk (ASV), and Elkem Spigerverket A/S. Under the plan, the Norwegian group would acquire an equity interest in Jamalco.

Spain.—Work continued through 1978-79 on the 800,000-ton-per-year San Ciprian alumina plant under construction on the northwest coast of Spain. The refinery is adjacent to a new reduction plant which began operation in 1979. The complex is operated by Alumina Española, SA, a company owned by Aluminio de Galicia, SA (45%), and Empresa National del Aluminio, SA (55%). Alcan Aluminium Ltd. holds a 26.4% interest in the latter company. When the alumina plant reaches its designed output capacity in 1980, it will consume annually 1.6 million tons of bauxite supplied principally from Boké, Guinea. The facility was planned to permit enlargement to 1.6-million-ton capacity in the future. At rated capacity production, Spain's five aluminum smelters (including the new San Ciprian smelter), require about 800,000 tons of alumina annually, the designed output capacity of the San Ciprian refinery. Thus, Spain could become self-sufficient in alumina production.[4]

Suriname.—Two companies, Billiton Mij. Suriname (a Royal-Dutch Shell subsidiary) and Suriname Aluminum Co. (Suralco, an Alcoa subsidiary), operated mines in the northeast region. All of Suriname's alumina was produced at Suralco's plant at Paranam, using bauxite supplied both by Suralco and, under a tolling agreement, by Billiton.

In West Suriname, bauxite deposits in the Bakhuys Mountains were jointly explored by Reynolds Suriname Mines (a Reynolds Metals Co. subsidiary) and the Suriname Government during the period 1971-74. After Reynolds sold its interest in the project to the Government in 1975, Suriname proceeded to develop the 280-million-ton deposit through its now wholly owned company, Grassalco. A 72-kilometer railroad was to be completed in 1980, connecting the Bakhuys mine site with a Corantijn River port at Apoera. Overall plans for West Suriname included the 500-megawatt Kabalebo Hydroelectric Project which would eventually provide power for an alumina refinery and an aluminum plant.

United Kingdom.—Baco, announced plans to increase by 10% the capacity of its Burntisland, Scotland, alumina plant. This would raise the capacity of Britain's only alumina producer from 130,000 tons to 143,000 tons per year by 1979. The entire output of the facility was used for the production of alumina-based chemicals rather than for metal production. In the third quarter of 1978, Reynolds Metals Co. sold its 48% equity interest in Baco.

U.S.S.R.—PUK was constructing a 1-million-ton-per-year alumina plant for the Government near Odessa on the Black Sea. The plant will use imported bauxite and was expected to be in operation in 1980. Facilities to produce alumina from nonbauxite materials reportedly accounted for an estimated 21% of the alumina production in the U.S.S.R. in 1978.[5]

Venezuela.—A significant expansion in 1978-79 of Venezuela's primary aluminum capacity resulted in sharply increased demand for alumina. Late in 1977, the state-owned Corporatión Venezolana de Guayana (CVG) announced the formation of Interamericana de Alúmina, CA (Interalumina) to build and operate a 1.1-million-ton-per-year alumina plant at Ciudad Guayana on the Orinoco River. In 1979 the new company was restructured, reducing the number of partners from three to two, with CVG holding 89% and Alusuisse 11%.

The 1976 discovery of bauxite at Los Pijiguaos led CVG to create a second company, CVG Bauxita Venezolana (Bauxivén), to study and develop the ore deposits. Alusuisse was contracted to complete the initial prospecting and feasibility study, which was concluded by the end of 1979 after completion of 21,000 meters of drilling. The initial proven ore reserve figures were reported to be 200 million tons of bauxite containing over 49% Al_2O_3 and less than 8% SiO_2. Potential resources were estimated to be in excess of 500 million tons. Bauxite transportation from the mine to the alumina plant at Ciudad Guayana would involve the use of overland and barge systems for the 775-kilometer distance. The new Interalumina plant will be supplied with imported bauxite when it begins production in 1982. If proved economically feasible, bauxite mined at Los Pijiguaos would gradually replace the imported ore.

Yugoslavia.—Two new alumina plants came onstream in the second half of 1978, and production was gradually increased through 1979. The Jadral plant at Obrovac in Croatia was expected to reach its rated annual capacity of 300,000 tons by 1981. The Energoinvest plant at Birac near Zvornik, Bosnia-Herzegovina, had a 600,000-ton-per-year capacity at the end of 1979. The Titograd refinery was being enlarged from a 1978 annual capacity of 500,000 tons of alumina to 1 million tons by 1980, and a goal of 1.5 million tons by 1985 was established.[6]

Table 18.—Bauxite: World production by country

(Thousand metric tons)

Continent and country	1976	1977	1978[p]	1979[e]
North America and Caribbean Islands:				
Dominican Republic[1] [2]	517	583	568	570
Haiti[3]	660	588	580	530
Jamaica[4]	10,312	11,433	11,736	[5]11,574
United States[1]	1,989	2,013	1,669	[5]1,821
South America:				
Brazil[6] [e]	[r]827	1,120	1,160	2,400
Guyana[e] [1]	2,686	2,731	2,400	2,400
Suriname	[r]4,587	4,856	5,025	5,000
Europe:				
France[7]	2,330	2,059	1,990	2,000
Germany, Federal Republic of	(8)	(8)	(8)	(8)
Greece	2,551	2,984	2,630	[5]2,915
Hungary	2,918	2,949	2,899	3,000
Italy	24	35	24	20
Romania	[r]680	702	708	708
Spain	13	5	[e]5	10
U.S.S.R.[e] [9]	4,500	4,600	4,600	4,600
Yugoslavia	2,033	2,044	2,566	[5]3,012
Africa:				
Ghana	[r]272	244	328	300
Guinea	11,316	11,300	12,000	12,500
Mozambique	[r]2	--	--	--
Rhodesia, Southern[e]	2	2	--	--
Sierra Leone	[r]651	745	[e]716	720
Asia:				
China, mainland	[r]1,000	1,200	1,400	1,500
India	1,448	1,511	1,653	1,600
Indonesia	940	1,301	1,008	1,000
Malaysia	660	616	615	700
Pakistan	(8)	(8)	2	1
Turkey	461	667	454	350
Oceania: Australia	24,084	26,086	24,298	[5]27,583
Total	[r]77,463	82,374	81,029	86,814

[e] Estimate. [p] Preliminary. [r] Revised.

[1] Dry bauxite equivalent of crude ore.

[2] Shipments.

[3] Dry bauxite equivalent of ore processed by drying plant.

[4] Bauxite processed for conversion to alumina in Jamaica plus exports of kiln-dried ore.

[5] Reported figure.

[6] Estimated dry bauxite equivalent of crude ore, calculated from reported crude ore, assuming a moisture content of 17.2%.

[7] Includes bauxite identified as "usable for fabrication of alumina" as follows, in thousand metric tons: 1976—2,250; 1977—1,966; 1978—1,875; 1979—(estimate) 1,990.

[8] Less than 1/2 unit.

[9] In addition to the bauxite reported in the body of the table, the U.S.S.R. produces nepheline syenite concentrate and alunite ore as sources of aluminum. Estimated nepheline syenite production was as follows, in thousand metric tons: 1976—2,400; 1977-2,500; 1978—2,500; 1979—2,500, and estimated alunite ore production was as follows, in thousand metric tons: 1976—600; 1977—600; 1978—600; 1979—600. Nepheline syenite concentrate grades 25% to 30% alumina and alunite ore grades 16% to 18% alumina; these commodities may be converted to their bauxite equivalent by using factors of 1 ton of nepheline syenite concentrate equals 0.55 ton of bauxite and 1 ton of alunite equals 0.34 ton of bauxite.

Table 19.—Alumina: World production[1] by country

(Thousand metric tons)

Continent and country[2]	1976	1977	1978[p]	1979[e]
North America:				
Canada	[r]490	1,061	1,054	900
Jamaica	1,621	2,036	2,142	[3]2,074
United States[e]	5,800	[r]6,030	5,960	6,450
South America:				
Brazil	303	372	390	410
Guyana[4]	281	271	250	200
Suriname	[r]1,162	1,215	1,316	1,250
Europe:				
Czechoslovakia[e]	90	95	100	100
France	1,020	1,081	1,056	[3]1,075
German Democratic Republic	44	39	38	36
Germany, Federal Republic of	1,333	1,454	1,410	1,400
Greece	450	474	482	[3]495
Hungary	[r]732	783	782	800
Italy	750	792	809	810
Romania[e]	[r]425	[r]442	449	500
United Kingdom	96	99	94	100
U.S.S.R.[e]	2,500	2,600	2,600	2,600
Yugoslavia	455	499	494	900
Africa: Guinea	560	562	610	660
Asia:				
China:				
Mainland[e]	[r]400	500	600	650
Taiwan	48	51	51	60
India	442	[e]390	480	450
Japan	1,411	1,785	1,524	1,500
Turkey	139	[e]170	[e]85	140
Oceania: Australia	6,206	6,659	6,776	[3]7,416
Total	26,758	29,460	29,552	30,976

[e] Estimate. [p] Preliminary. [r] Revised.

[1] Figures presented generally represent calcined alumina; exceptions are noted individually.

[2] In addition to the countries listed, Austria produces alumina (fused aluminum oxide), but output is entirely for abrasives production. Output totaled 28,223 metric tons in 1973; production data subsequent to 1973 are not available.

[3] Reported figure.

[4] Calcined alumina plus calcined alumina equivalent of alumina hydrate.

Table 20.—World annual alumina capacity

(Thousand metric tons, yearend)

Country	1976	1977	1978	1979
North America:				
Canada	[r]1,225	[r]1,225	1,225	1,225
Jamaica	3,053	3,053	2,824	2,824
United States	7,080	7,140	7,208	7,208
South America:				
Brazil	390	390	430	460
Guyana	354	354	354	354
Suriname	1,350	1,350	1,350	1,350
Europe:				
Czechoslovakia	100	100	100	100
France	1,306	1,306	1,320	1,320
German Democratic Republic	65	65	65	65
Germany, Federal Republic of	1,729	1,729	1,729	1,729
Greece	500	500	500	500
Hungary	772	790	790	817
Italy	920	920	920	920
Romania	500	500	540	540
United Kingdom	125	130	130	138
U.S.S.R.[e]	3,175	3,400	3,400	3,400
Yugoslavia	620	620	1,560	1,600
Africa: Guinea	700	700	700	700
Asia:				
China:				
Mainland[e]	[r]450	[r]500	600	650
Taiwan	75	140	140	140
India	679	682	675	675
Japan	2,634	2,634	2,614	2,614
Turkey	200	200	200	200
Oceania: Australia	6,740	6,836	7,044	7,044
Total	34,741	35,263	36,418	36,573

[e] Estimate. [r] Revised.

TECHNOLOGY

The Federal Bureau of Mines continued its research program on the recovery of alumina from clay, anorthosite, and other raw materials abundant in the United States. The most promising technologies for extracting alumina were being tested and developed in miniplants at the Bureau's Boulder City (Nev.) Engineering Laboratory. Additional research in support of this effort was being conducted at other Bureau research centers. The miniplant program was initiated to evaluate the various processes on a comparative basis and to obtain cost and engineering data for the design and possible operation of a large-scale demonstration plant. Five companies were participating with the Bureau in the miniplant project on a cooperative cost-sharing basis. In 1979 the major emphasis of the miniplant project was on the hydrochloric acid process for recovering alumina from clay. Test runs of several sections of this miniplant were completed.

The second and third tasks of a three-part, $1.6 million contract awarded by the Bureau to Kaiser Engineers in 1976 were completed. The third task was for the design of a 25-ton-per-day alumina pilot plant based on the most promising process as determined from the second task of the contract.

A contract, awarded by the Bureau to the Colorado School of Mines Research Institute for a study on the environmental factors involved in metallurgical processing utilizing domestic resources in the production of alumina was completed.

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[1] Physical scientist, Section of Nonferrous Metals.

[2] Statistical assistant, Section of Nonferrous Metals.

[3] Mining Magazine. Bauxite Mining Developments in Hungary. V. 138, No. 1, January 1978, p. 11.

[4] Metal Bulletin Monthly. No. 111, March 1980, pp. 27-31.

[5] Strishkov, V. V. Mineral Industries of the U.S.S.R. Mining Ann. Review, 1979, pp. 569-571.

[6] The Economics of Aluminium, First Edition. Roskill Information Service Ltd., August 1979, p. 29.

Beryllium

By Benjamin Petkof[1]

During 1978 and 1979 low-grade bertrandite ore, mined in Utah, was the only commercial source of industrial quantities of domestic beryllium minerals and was a significant fraction of the world beryllium mineral supply. Only a minor quantity of beryl was produced domestically. Consumption and imports of beryllium ore increased, and exports of beryllium materials decreased.

Table 1.—Salient beryllium mineral statistics

	1975	1976	1977	1978	1979
United States:					
Beryllium mineral concentrates:					
Shipped from mines[1] short tons	W	W	W	W	W
Imports do	1,479	1,058	746	1,031	1,037
Consumption[1] do	4,850	3,740	4,165	5,916	9,518
Price, approximate, per unit BeO, imported cobbed beryl at port of exportation	$32	$36	$40	$43	$47
Yearend stocks[1] short tons	3,546	3,957	3,557	1,346	835
World production of beryl do	3,290	[r]2,553	[r]2,748	3,094	3,082

[r]Revised. W Withheld to avoid disclosing company proprietary data.

[1]Includes bertrandite ore, which was calculated as equivalent to beryl containing 11% BeO.

Legislation and Government Programs.—Strategic stockpile goals issued on October 1, 1976 by the Federal Preparedness Agency of the General Services Administration remained unchanged during 1978-79. No beryllium materials were released from the strategic stockpiles during both years.

The Occupational Safety and Health Administration (OSHA), U.S. Department of Labor, did not finalize its proposed beryllium occupational and health standards, as published in the Federal Register, October 17, 1975.

DOMESTIC PRODUCTION

Brush Wellman, Inc. (Brush) was the only major commercial domestic producer of beryllium concentrates in 1978-79. Brush mined low-grade bertrandite ore at its Spor Mountain, Utah, operation for processing into beryllium hydroxide. Reported production of beryl was minor in both years.

Brush converted its ore to beryllium hydroxide at a facility north of Delta, Utah, and shipped the hydroxide to its Elmore, Ohio, facility and elsewhere for conversion into various beryllium products. Brush also had the capability to convert imported beryl to beryllium hydroxide at Delta, Utah. In October 1979, Brush announced plans to increase the capacity of its Delta, Utah, facility to process bertrandite ore.

Kawecki-Berylco Industries, Inc. (KBI) became a wholly owned subsidiary of the Cabot Corp. in May 1978. KBI produced beryllium metal, alloys, and oxide at its plants in Hazleton and Reading, Pa., from imported ore that was converted to beryllium hydroxide. In 1979, KBI announced that effective October 1, 1979, the company would produce only beryllium-copper alloy and cease the production of beryllium metal.

Domestic production of beryllium metal, beryllium oxide, and beryllium-copper master alloy in 1978-79 increased over that of 1977.

CONSUMPTION AND USES

In 1978-79 the domestic beryllium industry consumed beryllium ore equivalent to 5,916 and 9,518 tons of beryl, respectively, containing a nominal 11% BeO.

Products utilizing beryllium-copper alloys accounted for the greatest quantity of beryllium consumption. These alloys were used by the business machine, appliance, transportation, and communications industries. Beryllium-copper alloys were also widely used in electrical and electronic systems for connectors, sockets, switches, and temperature- and pressure-sensing devices to provide reliability and long service life.

Beryllium oxide (beryllia) ceramics were used in lasers, microwave tubes, and semiconductors, primarily for heat dissipation. Beryllia was used also as a substrate in various electronic devices and equipment.

Beryllium metal, with its high stiffness-to-weight ratio and excellent thermal properties, was used in items such as inertial navigation systems, satellite structures, space optics, nuclear devices, and military aircraft brakes.

STOCKS

Consumer stocks of beryllium minerals containing 11% BeO totaled 1,346 tons at yearend 1978, and 835 tons at yearend 1979. The drawdown of beryllium mineral yearend stocks reflected increased beryllium mineral consumption and the low quantity of beryllium mineral imports.

PRICES AND SPECIFICATIONS

From January 1978 to the end of August 1978, Metals Week quoted the price of imported beryl at $40 to $42 per short ton unit of contained BeO. For the remainder of 1978, imported beryl was quoted at $45 to $50 per short ton unit. At the beginning of 1979, beryl ore price went to $50 to $53 per short ton unit and remained at that level throughout 1979.

At yearend 1978, the American Metal Market quoted the following prices for beryllium materials: Vacuum-cast ingot, $120 per pound; metal beads (1,000-pound lots), $93 per pound; metal powder (5,000-pound lots), $103 per pound; beryllium-copper master alloy, $67 per pound of contained beryllium; beryllium-copper casting alloy, $2.75 to $3.40 per pound; beryllium-copper in rod, bar and wire, $4.79 per pound; beryllium-copper in strip, $4.77 per pound; beryllium-aluminum alloy ingot (100,000 pound lots), $83 per pound; and beryllium oxide powder, $26 per pound. All beryllium metal quotations were for 97%-purity metal.

At the end of 1979, the price quotations for vacuum-cast ingot, metal beads and powder, and oxide remained unchanged. Other beryllium categories were as follows: Beryllium-copper master alloy, $72.50 per pound of contained beryllium; beryllium-copper rod, bar and wire, $5.56 per pound; beryllium-copper strip, $5.54 per pound; beryllium-aluminum alloy, $98 per pound.

FOREIGN TRADE

Although the quantity of wrought and unwrought beryllium alloys and waste and scrap exports declined in 1978-79, the annual average value of exports increased, indicating that greater quantities of finished forms of beryllium metal and alloy were exported.

Beryl was the only beryllium mineral ore imported. The average value of the imported material rose from $399 per ton in 1977, to $404 per ton in 1978, and $471 per ton in 1979. In addition, 1,455 pounds of wrought, unwrought and waste and scrap beryllium metal valued at $11,226 was imported from Mexico and France in 1978, and 2,107 pounds valued at $9,182 from Canada and the United Kingdom in 1979.

Table 2.—U.S. exports of beryllium alloys, wrought or unwrought, and waste and scrap[1]

Country	1977		1978		1979	
	Quantity (pounds)	Value (thousands)	Quantity (pounds)	Value (thousands)	Quantity (pounds)	Value (thousands)
Argentina	967	$21	2	$2	291	$3
Australia	797	3	2,271	2	--	--
Belgium-Luxembourg	549	5	88	1	112	66
Canada	44,472	28	3,400	245	10,698	211
Ecuador	--	--	800	1	--	--
El Salvador	--	--	33,534	6	--	--
French West Indies	--	--	400	1	--	--
Finland	5	5	4	3	86	19
France	13,414	571	5,471	590	17,370	1,635
Germany, Federal Republic of	855	65	8,013	169	1.022	195
Hong Kong	--	--	1,161	3	2,200	11
India	--	--	169	4	253	8
Israel	3	2	491	4	--	--
Italy	56	1	150	7	249	6
Jamaica	832	4	--	--	--	--
Japan	84,410	624	3,305	244	4,691	397
Mexico	4,000	9	3,128	19	326	21
Netherlands	1,356	38	207	56	1,057	40
New Zealand	--	--	--	--	65	1
Norway	--	--	--	--	192	2
Singapore	--	--	222	1	1,367	6
Switzerland	30	11	1,570	41	3,939	50
Taiwan	--	--	3,696	9	4,000	15
United Kingdom	7,912	521	13,597	577	23,915	999
Venezuela	--	--	--	--	319	1
Other	847	3	--	--	--	--
Total	160,505	1,911	81,679	1,985	72,152	3,686

[1] Consisting of beryllium lumps, single crystals, powder; beryllium-base alloy powder; beryllium rods, sheets, and wire.

Table 3.—U.S. imports for consumption of beryl, by customs district and country

Customs district and country	1977		1978		1979	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Philadelphia district:						
Argentina	66	$22	--	--	--	--
Australia	15	3	--	--	--	--
Brazil	370	162	237	$114	187	$94
China, People's Republic of	--	--	--	--	265	115
India	--	--	553	211	--	--
Rwanda	--	--	--	--	110	77
South Africa, Republic of	32	12	--	--	21	8
Spain	9	4	--	--	--	--
Total	492	203	790	325	583	294
Los Angeles district:						
Argentina	111	38	69	24	84	40
Brazil	99	42	144	58	331	141
Mozambique	22	6	--	--	22	6
Rwanda	22	9	--	--	--	--
South Africa, Republic of	--	--	28	10	17	7
Total	254	95	241	92	454	194
Grand total	746	298	1,031	417	1,037	488

WORLD REVIEW

World beryl production remained low in 1978-79 in response to limited industrial requirements for beryllium products. Argentina, Brazil, and the U.S.S.R. were the major world beryl producers. The United States retained its position as a significant producer of commercial beryllium minerals by mining and processing bertrandite ore in Utah. The U.S.S.R. and the United States were the major consumers of beryllium concentrates.

Table 4.—Beryl: World production, by country[1]

(Short tons)

Country	1976	1977	1978[p]	1979[p]
Argentina	123	182	219	200
Brazil	406	496	815	800
Madagascar	19	[e]15	12	11
Mozambique	(2)	NA	NA	--
Nepal[3]	[e]1	1	(2)	--
Rhodesia, Southern[e]	70	70	50	50
Rwanda	51	61	64	21
South Africa, Republic of	3	3	4	--
Uganda[e]	60	50	NA	--
U.S.S.R.[e]	1,820	1,870	1,930	2,000
United States[4]	W	W	W	W
Total	[r]2,553	[r]2,748	3,094	3,082

[e] Estimate. [p] Preliminary. [r] Revised. NA Not available. W Withheld to avoid disclosing company proprietary data.

[1] In addition to the countries listed, Bolivia and the Territory of South-West Africa (Namibia) may also have produced beryl, but available information is inadequate to formulate reliable estimates of output levels.

[2] Less than 1/2 unit.

[3] Fiscal year ending in July of year stated.

[4] Primarily bertrandite ore.

TECHNOLOGY

Hazards associated with milling, sawing, welding, and brazing of beryllium-copper alloys were evaluated experimentally. The study concluded that beryllium-copper alloys should be treated as toxic materials and air samples should be taken for each fabrication method to determine worker exposure and effectiveness of workplace controls.[2]

An experimental program was conducted to develop a material-process combination that would produce a high-quality beryllium-titanium composite. The resulting composite had a proportional limit equal to or greater than 40,000 pounds per square inch, an elastic modulus of 28 million pounds per square inch, and a density of 3.32 grams per cubic centimeter.[3]

Scientific literature was reviewed to assess the biological and environmental effects of beryllium. The review included a general summary and discussion of beryllium topics such as physical and chemical properties; occurrence, synthesis and use; analytical methodology; biological aspects in micro-organisms, plants, animals, and humans; distribution, mobility, and persistence in the environment; assessment of present and potential health and environmental hazards; and standards and governmental regulations. The review cited a large number of references.[4]

The beryllium standards proposed by OSHA and their impact on some end uses were discussed.[5]

The use of beryllium oxide and other substrates for mounting power components such as transistors and diodes was described.[6]

Beryllium-nickel alloy was considered for the fabrication of connectors that function above the range of 150°F to 300°F, the limit of conventional connectors, because of its high yield strength and high resistence to stress relaxation above 300°F.[7]

A brief article described the characteristics and uses of beryllium- nickel alloy.[8]

Specific uses for beryllium-copper alloys were discussed along with some description of the required alloy treatment.[9]

The toxic effect of beryllium on potatoes and oats was measured when grown in a beryllium-contained acid soil. The uptake of beryllium by the plants was also measured.[10]

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[1] Physical scientist, Section of Nonferrous Metals.

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Bismuth

By James F. Carlin, Jr.,[1] and Robert J. Bascle[1]

Domestic consumption of bismuth was 2.5 million pounds in 1978 and 2.7 million pounds in 1979 compared with 2.4 million pounds in 1977. Imports increased in 1978 because of greater domestic consumption and lower production. Exports in 1979 were over four times those of 1978, while imports declined by 18% because of higher domestic production. The domestic producer price for refined bismuth fell from $4.50 per pound to $2.50 per pound in 1978, but by yearend 1979 was $3 per pound. World bismuth mine production was 9.7 million pounds in 1978 but fell to 9.4 million pounds in 1979.

Legislation and Government Programs.—Throughout 1978 and 1979, Government stocks remained at 2,081,298 pounds, including 567,186 pounds in the national stockpile and 1,514,112 pounds in the supplemental stockpile. The stockpile goal of 771,000 pounds for bismuth remained unchanged, and no action was taken to dispose of the 1,310,298 pounds of excess.

Federal income tax laws provided a percentage depletion allowance of 22% for domestic production and 14% for U.S. companies producing from foreign sources.

Table 1.—Salient bismuth statistics

(Pounds)

	1975	1976	1977	1978	1979
United States:					
Consumption	1,406,021	2,410,584	2,379,635	2,511,876	2,727,158
Exports[1]	128,893	68,488	95,334	96,346	427,809
Imports, general	1,331,173	2,328,051	2,013,333	2,657,763	2,167,278
Price: New York, average per pound (ton lots)	$7.72	$7.50	$6.01	$3.38	$3.01
Consumer stocks, Dec. 31:	451,250	483,810	436,092	781,868	629,741
World: Production[2]	8,776,000	[r]8,786,000	[r]9,868,000	9,745,000	9,422,000

[r] Revised.

[1] Includes bismuth, bismuth alloys, and waste and scrap.

[2] Excludes the United States.

DOMESTIC PRODUCTION

Bismuth was produced almost entirely from the treatment of lead ores and bullion of both foreign and domestic origin. A single primary refinery operated by ASARCO Incorporated at Omaha, Nebr., accounted for all primary production. United Refining and Smelting Co., Franklin Park, Ill., recovered a small quantity of bismuth by recycling scrap material. Refinery production statistics are withheld to avoid disclosing company proprietary data.

CONSUMPTION AND USES

A significant increase in bismuth usage in the metallurgical additive category from 1978 to 1979 was largely attributed to a continued strong economy, especially in the various specialized end uses for which malleable iron castings find application.

Table 2.—Bismuth metal consumed in the United States, by use

(Pounds)

Use	1977	1978	1979
Fusible alloys	611,219	836,021	721,043
Metallurgical additives	461,573	485,284	703,770
Other alloys	18,617	21,774	22,029
Pharmaceuticals[1]	1,274,510	1,149,683	1,248,656
Experimental uses	601	558	3,153
Other uses	13,115	18,556	28,502
Total	2,379,635	2,511,876	2,727,153

[1] Includes industrial and laboratory chemicals and cosmetics.

STOCKS

From the beginning of 1978 to the end of 1979, consumer stocks fluctuated but generally rose, paralleling the general softness in the price of bismuth during this period.

PRICES

In 1978, ASARCO held its price for bismuth at $4.50 per pound through February. In response to weak demand, the company lowered the price to $3.50 in March, $3 in July, and $2.50 in November. Dealer quotations started the year at $2.70 to $2.80 per pound and ended the year at $1.72 to $1.84 per pound.

In 1979, ASARCO maintained its price at $2.50 per pound through early May. At that time, in response to a rising dealer market price, ASARCO raised its price to $4 per pound. The market price fell during the ensuing weeks, and ASARCO cut its price to $3.50 per pound on June 20. Scant consumer demand continued to weaken the market price and on July 24 ASARCO lowered the price to $3 per pound and held it there for the rest of the year. Dealer quotations started the year at $1.72 to $1.84, peaked at $4.25 to $4.50 in May, and ended the year at $2.50 to $2.60 per pound.

FOREIGN TRADE

The large increases in exports of bismuth in all forms to the Netherlands and the United Kingdom in 1979 were attributed to a heavy demand from Eastern European countries in the second quarter of that year.

The imports of metallic bismuth were mainly from Mexico, the Federal Republic of Germany, the United Kingdom, Japan, Belgium-Luxembourg, and Peru in 1978. In 1979, Peru became the major supplier and the Republic of Korea became a significant source.

The United States established new tariff rates for bismuth, with different rates set for Most Favored Nation (MFN) and Non-Most Favored Nation (Non-MFN) statuses. Effective January 1, 1980, the rates were unwrought metal (No. 632.10), free (MFN) and 7.5% ad valorem (Non-MFN); alloys (No. 632.66), 8.6% ad valorem (MFN) and 45% ad valorem (Non-MFN); compounds (Nos. 418.00 and 423.80), 13.1% ad valorem (MFN) and 35% ad valorem (Non-MFN). Effective January 1, 1987, the rates for MFN status change to unwrought metal, free; alloys, 5.5% ad valorem; compounds, 7% ad valorem. Tariff rates were published in Tariff Schedules of the United States Annotated (1980).

Table 3.—U.S. exports of bismuth alloys, waste and scrap, by country

(Pounds, gross weight)

Country	1977		1978		1979	
	Quantity (pounds)	Value (thousands)	Quantity (pounds)	Value (thousands)	Quantity (pounds)	Value (thousands)
Argentina	1,079	$1	8,850	$66	2,875	$47
Belgium-Luxembourg	4,247	17	8,515	5	--	--
Brazil	--	--	627	12	2,604	7
Canada	17,648	181	22,927	135	13,853	224
France	--	--	--	--	550	11
Germany, Federal Republic of	390	3	2,168	39	6,095	14
India	9,686	106	1,060	1	4,446	16
Iran	--	--	734	2	--	--
Israel	200	1	--	--	1,202	9
Japan	425	8	31,758	136	5,414	39
Korea, Republic of	--	--	--	--	3,212	24
Mexico	--	--	3,375	3	304	2
Netherlands	47,479	247	84	1	329,340	906
Singapore	1,141	7	5,741	20	3,146	7
Spain	--	--	1,100	2	--	--
Sweden	--	--	359	1	4,400	17
Taiwan	--	--	345	1	3,008	7
United Kingdom	11,657	45	7,774	23	45,967	48
Venezuela	767	8	400	3	465	11
Other	615	13	529	7	928	19
Total	95,334	637	96,346	457	427,809	1,408

Table 4.—U.S. general imports[1] of metallic bismuth, by country

Country	1978		1979	
	Quantity (pounds)	Value (thousands)	Quantity (pounds)	Value (thousands)
Belgium-Luxembourg	344,042	$852	100,112	$74
Bolivia	55,023	173	--	--
Bulgaria	--	--	17,950	34
Canada	65,644	227	102,591	324
Germany, Federal Republic of	444,852	2,031	170,829	896
Japan	399,156	913	185,496	392
Korea, Republic of	61,547	172	230,781	398
Mexico	535,306	1,292	604,753	1,266
Netherlands	4,356	10	--	--
Peru	334,741	819	648,733	1,620
Spain	44	1	--	--
United Kingdom	413,052	1,820	106,033	414
Total	2,657,763	8,310	2,167,278	5,418

[1] General imports and imports for consumption were the same in 1978 and 1979.

WORLD REVIEW

World production of bismuth in 1978 and 1979 dropped successively lower than 1977 levels. This was attributed primarily to deliberate production reductions by several major world bismuth producers in response to the continued decline in the market price of bismuth. China reported a discovery in the Miyun area, northeast of Peking, that contained bismuth and other metals.

Australia.—Australia remained the leading world producer in 1978 and 1979. The main source of bismuth was a gold-bismuth bullion from the Mount Isa mine in Queensland, which was shipped to the United Kingdom for bismuth recovery and refining. Broken Hill Associated Smelters Ltd. announced plans to install a plant for bismuth removal at its Port Pirie lead smelter.

Bolivia.—The decline in production by Corporación Minera de Bolivia (COMIBOL) was due to lower world bismuth prices and work disruptions. Most of the bismuth was mined directly from complex copper-tin ores. The Quechisla group of mines, operated by COMIBOL in southern Bolivia, produced most of the country's output. COMIBOL operated the country's only bismuth smelter at Telamayu and the sole bismuth metal refinery at Quechisla. In 1979, Bolivia signed a contract with a European consortium to build a Kivcet smelter and a refinery at Karachipampa which will produce several metals including bismuth.

Canada.—Bismuth was produced by two companies in Canada. The bismuth refinery of the Belledune plant of Brunswick Mining & Smelting Corp. Ltd. was inactive during 1978 and 1979 owing to depressed bismuth prices, but this plant did produce a bismuth-lead alloy. Bismuth metal was produced by Cominco Ltd. at its lead-zinc plant at Trail, British Columbia. Most bismuth produced in Canada came from Canadian ores, with small amounts derived from imported ores. In 1979, Billiton Exploration Canada completed its 2-year feasibility study of the tungsten-bismuth-molybdenum deposit, owned by the Sullivan Mining Group. The deposit was to be mined with Billiton and Sullivan as equal partners, but there were no plans to recover the bismuth owing to weak market conditions.

Korea, Republic of.—The principal producer of bismuth metal in Korea was Korea Tungsten Mining Co., Ltd., accounting for more than half the total output. The company's bismuth production was a byproduct of tungsten mining from the Sangtong mine in Kangwong Province. The refinery is located in Daegu.

U.S.S.R.—Bismuth output in the U.S.S.R. continued its rising trend of recent years. Production was almost entirely from complex ores such as the tungsten-bismuth-molybdenum ores of North Caucasus. Scheelite and cassiterite ores in Kazakhstan and Siberia were also processed for byproduct bismuth. Two copper-bismuth deposits were under exploration in Tadzhikistan.

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[1] Physical scientist, Section of Nonferrous Metals.

Table 5.—Bismuth: World mine production, by country[1]

(Thousand pounds)

Country[1]	1976	1977	1978^{p}	1979^{e}
Australia (in concentrates)	^{r}1,650	2,054	2,050	2,100
Bolivia (in concentrates)	1,349	1,508	1,063	1,000
Canada[2]	286	363	348	400
China, mainland (in ore)^{e}	550	550	660	660
France (metal)[3]	139	115	^{e}130	100
Germany, Federal Republic of (in ore)^{e}	^{r}24	24	20	20
Japan (metal)[3]	^{r}1,502	1,538	1,355	1,400
Korea, Republic of (metal)[3]	384	295	269	400
Mexico[4]	1,228	1,607	2,156	1,500
Peru[4]	1,149	1,290	^{e}1,300	1,400
Romania (in ore)^{e}	180	180	180	180
Sweden (in ore)^{e}	33	33	33	30
Uganda (in ore)^{e}	10	7	2	10
U.S.S.R. (metal)[2]^{e}	130	^{r}140	150	160
United States (in ore)	W	W	W	W
Yugoslavia (metal)[3]	172	164	29	62
Total	^{r}8,786	^{r}9,868	9,745	9,422

^{e}Estimate. ^{p}Preliminary. ^{r}Revised. W Withheld to avoid disclosing company proprietary data.

[1] In addition to the countries listed, Brazil, Bulgaria, the German Democratic Republic, and the Territory of South-West Africa (Namibia) are believed to have produced bismuth, but available information is inadequate for formulation of reliable estimates of output levels.

[2] Refined metal and bullion plus recoverable bismuth content of exported concentrate.

[3] Although output reported is at the smelter stage of production rather than at the mine stage, and thus could include metal contained in ores mined in other countries, it is believed that any such production derived from ores from other countries is not duplicative to any significant extent of mine production reported elsewhere in this table.

[4] Bismuth content of refined metal, bullion, and alloys produced indigenously, plus recoverable bismuth content of ores and concentrates exported for processing.

Boron

By Sandra T. Absalom[1]

U.S. production and sales of boron minerals and chemicals climbed to record high levels in 1978 and 1979. Markets for energy-saving materials, spurred by rising fuel prices and the national energy conservation program, were responsible for the strong derived demand for borates in insulation products and glass-fiber-reinforced plastics. Glass-fiber insulation (glass wool) continued to be the largest end use for borates, followed by textile-grade glass fibers, and special borosilicate glasses. Demand for borates in cellulosic insulation (paper wool) declined from its 1977 peak, but began to grow again in 1979.

California was the domestic source of boron minerals, which were mostly in the form of sodium borate, but also as calcium borate and sodium-calcium borates. Notwithstanding the fact that most domestic borate markets were the strongest ever, the United States continued to provide most of its own supply while maintaining its position as the primary source of sodium borate products and boric acid to foreign markets.

Supplementary U.S. imports of Turkish calcium and sodium-calcium borate ores, primarily for textile-grade and insulation-grade glass fiber manufacture, respectively, nearly doubled in 1978, but declined in 1979 when shipments ceased following nationalization of private Turkish mines.

Table 1.—Salient statistics of boron minerals and compounds in the United States

(Thousand short tons and thousand dollars)

	1975	1976	1977	1978	1979
Sold or used by producers:					
Quantity:					
Gross weight	1,172	1,246	1,469	1,554	1,590
Boron oxide (B_2O_3) content	603	630	735	778	799
Boron content	188	196	228	242	248
Value	$158,772	$184,852	$236,163	$279,927	$310,211
Exports:					
Sodium borates (refined):[1]					
Quantity	212	211	265	304	332
Value	$42,486	$49,156	$64,634	[e]$80,000	[e]$94,000
Boric acid:[2]					
Quantity	34	36	36	46	42
Value	$11,532	$12,363	$12,931	$22,217	$22,938
Imports for consumption:					
Colemanite:					
Quantity	28	30	51	[3]94	[3]81
Value	$1,560	$1,953	$3,695	$9,320	$10,946
Boric acid:					
Quantity	(4)	(4)	14	16	8
Value	$59	$14	$5,596	$8,921	$4,267
Apparent consumption: Boron content[5]	85	94	121	128	127

[e] Estimate.

[1] Comparable quantities of crude sodium borates are exported also; however, export data are not available.

[2] Includes orthoboric and anhydrous boric acid.

[3] Includes approximately 23,000 tons of ulexite in 1978 and 10,000 tons in 1979.

[4] Less than 1/2 unit.

[5] Measured by domestic boron sold or used plus imports.

DOMESTIC PRODUCTION

Production from Kern County, Calif., provided over three-quarters of the supply, and San Bernardino and Inyo Counties provided the balance. U.S. boric acid production (which also is centered in California) was 193,000 tons in 1978 and 189,000 tons in 1979, based on the monthly production reports published by the U.S. Department of Commerce. According to the results of the Bureau of Mines annual canvass of the three major boric acid producers, sales to domestic and foreign customers amounted to 176,600 tons valued at $57 million in 1978 and 170,600 tons valued at $60 million in 1979.

At Boron, in Kern County, the open-pit tincal-kernite mine and adjacent refining plant of U.S. Borax and Chemical Corp., a member of the RTZ Group of London, England, continued to be the primary world supplier of sodium borates. U.S. Borax processed crude and refined hydrated sodium borates and their anhydrous derivatives, and anhydrous boric acid at the the Boron refinery. A second plant at Wilmington, Los Angeles County, produced boric acid and a variety of specialty chemicals. In 1978, U.S. Borax began construction of a new boric acid production plant at Boron. Due for completion in 1980, the 200,000-ton-per-year facility is expected to have double the capacity of the existing Wilmington plant, which eventually will phase out production of technical-grade boric acid.

U.S. Borax increased output and sales of all primary borate products in both 1978 and 1979. Output of refined decahydrate, pentahydrate, and anhydrous borax for domestic and foreign customers accounted for about three-fifths of the company's total sales. Crude sodium borates—Rasorite 46 (a pentahydrate) and its anhydrous derivative—were produced for foreign markets. Boric acid production at the Wilmington plant increased 10% in 1978 and remained at the 1978 level in 1979.

The Wilmington facilities also served as a warehouse and overseas shipping point for bulk shipments. A large percentage of U.S. Borax's exports were shipped to Europe by way of a warehouse and distribution facility at Botlek, near Rotterdam, Netherlands. RTZ Borax, Ltd., another member of the RTZ Group, maintains this facility. U.S. Borax operated a plant and warehousing facility at Burlington, Iowa, for compounding, packaging, and distributing household soaps and other consumer products to the Eastern and Midwestern United States.

Kerr-McGee Chemical Corp. operated the Trona and Westend plants at Searles Lake in San Bernardino County to produce refined sodium borate compounds and boric acid from the mineral-rich lake brines. Coproducts included potassium compounds, soda ash, and salt cake. At the Trona plant, Kerr-McGee utilized its differential evaporative process to produce boric acid and pentahydrate, decahydrate, and anhydrous borax. Additional boric acid was produced from weak lake brines and recycled plant liquors by solvent extraction. The carbonation process at the Westend plant produced sodium borates, some of which were subsequently used to manufacture boric acid.

As a result of Kerr-McGee's yearend 1977 installation of boric acid production equipment at Westend, output and sales of boric acid from both plants combined increased in 1978, while sodium borate sales decreased. Total output and sales were 11% below the 1977 levels. In 1979, Kerr-McGee readjusted its products ratio in accordance with perceived changes in demand, so that output and sales of sodium borates increased while boric acid production declined.

American Borate Co., another California producer, decreased sales of colemanite (calcium borate) and ulexite-probertite (two similar sodium-calcium borates mined and sold as one). The company's two open pit operations, located within the Death Valley National Monument in Inyo County, were completed in 1978, but underground extraction of ore from adits at the floors of each of the two pits began in 1979. American Borate was attempting to extend its stockpiled ore supply by reducing the average B_2O_3 content of its final products until the new Billie mine begins large-scale production.

Colemanite, destined primarily for textile-grade glass-fiber manufacturers, was processed at the washing and calcining plant at Lathrop Wells, Nev. During 1978, American Borate built and began operating a 100,000-ton-per-year flotation plant (adjacent to existing facilities at Lathrop Wells) to process colemanite. Ulexite-probertite ore was ground, screened, and blended to specification at storage and shipping facilities at Dunn, Calif., then transported by rail to customers. Most shipments went to manufacturers of glass-fiber insulation.

Development of the Billie mine, a joint venture since 1977 of American Borate's parent company, (Texas United Corp.) and Owens-Corning Fiberglas Corp. (OCF) was proceeding more slowly than planned. Toward yearend 1979, OCF announced that it had become the sole owner of the mine and other assets of American Borate Co.

CONSUMPTION AND USES

A Bureau of Mines canvass of U.S. producers collected data on domestic consumption of boron minerals and compounds. Tables 2 and 3 present the results of this survey. U.S. consumption of borates in 1979 was similar to that of 1978 in that insulation products and glass-fiber-reinforced plastics continued to be the most important consuming sectors, and total consumption was essentially unchanged.

The strong market for thermal insulation increased demand for borates (mostly borax pentahydrate and ulexite-probertite) in the manufacture of glass-fiber insulation; however, consumption decreased for a variety of boron chemicals and ores used as flame retardants in cellulosic insulation. This was the result of a considerable decline in 1978 in consumer demand for cellulosic material for reinsulating existing homes. In 1979, the cellulosic insulation industry experienced renewed vigor, and rising demand for orthoboric acid, borax, and ulexite-probertite forced producers to allocate supplies to customers. By yearend 1979, boric acid imports, which had become negligible since early 1978, were again growing rapidly. In table 3, figures for cellulosic insulation are somewhat misleading as a reflection of high-demand periods because of the delay in receiving shipments (particularly imports) after placing orders. Peak demand occurred in 1977 and secondarily in 1979.

The second major growth market for borates was textile-grade glass fibers. U.S. produced colemanite, orthoboric acid, anhydrous boric acid, and Turkish colemanite were essential raw materials for manufacturing high-tensile-strength glass-fiber composites for use in a range of products that include aircraft, automobiles, and sports equipment. The automobile industry's program to lower gasoline consumption by reducing vehicle weight has contributed to the rapid growth in demand for these lightweight composite materials.

Consumption of borates (colemanite, anhydrous borax, borax decahydrate and pentahydrate, orthoboric acid, and anhydrous boric acid) in the manufacture of special borosilicate glasses has remained at a high level, although growth has been negligible. Boron compounds in cleaning and bleaching have been an important but declining consumption sector. About one quarter of these compounds were used to produce sodium perborate detergents. Boron compounds find application in the manufacture of biological growth control chemicals for use in water treatment, algicides, fertilizers, herbicides, and insecticides. Boron compounds were also used in metallurgical processes as fluxes, as shielding slag in the nonferrous metallurgical industry, and as components in plating baths in the electroplating industry. Small amounts of boron and ferroboron were constituents of certain nonferrous alloys and of specialty steels, respectively.

Many important but small-percentage end uses for borates and boron-containing chemical derivatives comprised a diverse miscellaneous category. Another group of borate compounds were sold to chemical distributors, and their ultimate end uses are unknown.

Table 2.—U.S. consumption of boron minerals and compounds

(Short tons of boron content and short tons of boron oxide content)[1]

End use	1977		1978		1979	
	B	B_2O_3	B	B_2O_3	B	B_2O_3
Glass-fiber insulation	25,400	81,700	31,100	100,000	31,100	100,000
Fire retardants:						
Cellulosic insulation	18,300	58,800	15,600	50,200	15,300	49,100
Other	1,900	6,200	2,000	6,400	1,800	5,800
Textile-grade glass fibers	15,000	48,200	[r]16,900	[r]54,200	18,100	58,300
Borosilicate glasses	14,700	47,300	14,800	47,700	15,300	49,400
Soaps and detergents	13,700	44,000	11,700	37,600	12,000	38,700
Enamels, frits, glazes	5,200	16,600	[r]4,900	15,600	4,900	15,900
Agriculture	5,200	16,700	[r]6,300	[r]20,300	5,300	17,000
Metallurgy	1,300	4,200	[r]2,000	[r]6,500	1,800	5,900
Nuclear applications	180	590	225	725	140	460
Miscellaneous uses	9,100	29,400	10,400	33,600	9,300	29,800
Sold to distributors, end use unknown	11,100	35,700	12,400	39,700	12,300	39,500
Total consumption[2]	121,000	389,000	128,000	413,000	127,000	410,000

[r] Revised.

[1] Includes imports of boric acid, colemanite, and ulexite.

[2] Data may not add to totals shown because of independent rounding.

Table 3.—U.S. consumption of orthoboric acid

(Short tons)

End use	1977	1978	1979
Fire retardants:			
Cellulosic insulation[1]	45,300	45,500	39,800
Other	6,600	6,000	4,100
Textile-grade glass fibers	24,000	25,500	32,900
Borosilicate glasses	12,200	12,400	10,900
Metallurgy	2,000	2,800	2,300
Soaps and detergents	1,400	500	400
Enamels, frits, glazes	1,000	1,000	1,200
Nuclear applications	700	900	800
Agriculture	100	200	100
Glass-fiber insulation	--	--	--
Miscellaneous uses	23,300	27,000	24,700
Sold to distributors, end use unknown	20,700	30,200	22,100
Total consumption[2]	137,000	152,000	139,000

[1] Includes imports of 14,132, 16,277, and 7,704 tons in 1977, 1978, and 1979, respectively.

[2] Data may not add to totals shown because of independent rounding.

PRICES

General inflationary pressure plus the continued accelerating cost of energy for industrial purposes in California prompted the domestic producers to announce three price increases for refined sodium borate compounds and boric acid during 1978-79. Open market prices for boric acid declined in 1978 to a range of $500 to $600 per ton as the shortage situation of 1977 eased, but in 1979, signs of another impending shortage sent prices once again beyond the $1,000-per-ton level.

In an effort to channel demand for its energy-intensive calcined colemanite, American Borate Co. introduced a less costly flotation-processed product to the market in 1979.

Table 4.—Borate prices per short ton[1]

Product	Price, Dec. 31 (rounded dollars)	
	1978	1979
Borax, technical, anhydrous, 99%, bulk, carlots, works[2]	298	324
Borax, technical, granular, pentahydrate, 99.5%, bulk, carlots, works[2]	128	167
Borax, technical, granular, decahydrate, 99.5%, bulk, carlots, works[2]	109	117
Boric acid, technical, granular, 99.9%, bulk, carlots, works[2]	305-315	335-344
Boric acid, technical, granular, 99.9%, bags, carlots, works[2]	353-361	361-393
Boric acid, U.S. Borax & Chemical Corp., anhydrous, 96% B_2O_3, bulk, carlots, Boron, Calif	643	798
Colemanite, American Borate Co., calcined and screened, minus 70 mesh, 48% B_2O_3, bulk, carlots, Dunn, Calif	189	269
Colemanite, American Borate Co., flotation concentrate (uncalcined), 37% B_2O_3, bulk, carlots, Dunn, Calif	--	204
Colemanite, Turkish, 44%-46% B_2O_3, crude, lump, f.o.b. railcars, U.S. east coast port	215-220	240-246
Ulexite-probertite, American Borate Co., screened, minus 7 mesh, bulk, carlots, Dunn, Calif.[3]	45	55

[1] U.S. f.o.b. plant or port prices per short ton of product. Other conditions of final preparation, transportation, quantities, and qualities not stated are subject to negotiation and/or somewhat different price quotations.

[2] Chemical Marketing Reporter. V. 215, No. 1, Jan. 1, 1979, p. 47, and V. 216, No. 27, Dec. 31, 1979, p. 27.

[3] 23.5% B_2O_3 in 1978; 26% B_2O_3 in 1979.

FOREIGN TRADE

In 1978, the U.S. Bureau of the Census discontinued publishing export statistics on refined sodium borate compounds. Export data from a Bureau of Mines canvass are presented in table 5. Although export data on crude sodium borates (mostly Rasorite 46 of 48% B_2O_3 content) are not published, they were estimated to be comparable in volume to the exports of refined products.

U.S. imports from Turkey of commercial-grade colemanite and ulexite, principally for textile-grade and insulation-grade glass-fiber manufacture, nearly doubled in 1978. During the first 6 months of 1979, imports had nearly reached the 1978 level when they suddenly ceased. Difficulties in Turkey in implementing the nationalization of the privately owned borate mines were credited for the interruption of exports to the United States and other countries.

Table 5.—U.S. exports of refined sodium borate compounds

(Short tons)

Destination	1978	1979
Australia	8,283	8,291
Austria	368	328
Belgium-Luxembourg	6,509	7,780
Brazil	19,525	17,874
Canada	56,229	67,835
Chile	391	656
China:		
Mainland	4,796	15,520
Taiwan	8,456	9,443
Colombia	4,237	2,148
Costa Rica	1,773	2,109
Ecuador	137	290
El Salvador	711	130
Finland	483	664
France	16,407	21,068
German Democratic Republic	2,204	2,144
Germany, Federal Republic of	15,535	16,957
Guatemala	215	349
Hong Kong	4,411	4,541
Indonesia	3,638	2,464
Iran	1,180	55
Israel	166	431
Italy	8,685	9,511
Japan	53,222	52,607
Korea, Republic of	16,975	12,575
Malaysia	1,414	3,060
Mexico	25,727	30,387
Netherlands	4,411	5,064
New Guinea	105	108
New Zealand	3,315	2,851
Norway	45	68
Pakistan	199	248
Peru	51	164
Philippines	1,466	1,480
Portugal	473	384
Singapore	824	1,747
South Africa, Republic of	5,060	5,269
Spain	6,786	6,008
Sweden	564	368
Switzerland	1,969	1,128
Thailand	1,607	2,052
United Kingdom	11,155	9,737
Uruguay	239	314
Venezuela	1,931	1,800
Yugoslavia	754	671
Other[1]	1,311	3,610
Total	303,942	332,306

[1] Includes 25 countries in 1978 and 28 countries in 1979.

Source: U.S. exporters of sodium borates.

Table 6.—U.S. exports of boric acid[1]

Destination	1978		1979	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Argentina	2	$3	24	$1
Australia	2,705	1,626	1,865	1,205
Belgium-Luxembourg	143	73	395	190
Brazil	4,238	2,236	2,540	1,532
Canada	7,501	2,521	9,833	4,053
Chile	3	2	7	7
China:				
Mainland	--	--	165	94
Taiwan	1,029	551	1,008	588
Colombia	372	261	516	300
Costa Rica	33	24	14	10
Dominican Republic	23	18	14	12
Ecuador	9	6	39	17
El Salvador	63	9	6	6
Finland	--	--	59	33
France	19	7	41	26
Germany, Federal Republic of	2,568	1,463	699	358
Guatemala	8	4	21	13
Hong Kong	175	104	281	163
Indonesia	264	84	206	109
Iran	41	23	41	27
Israel	253	109	80	46
Italy	130	65	329	176
Jamaica	1	1	3	3
Japan	15,102	8,709	13,791	8,267
Korea, Republic of	3,385	851	1,628	797
Malaysia	70	45	76	41
Mexico	4,310	1,299	2,749	1,390
Netherlands	839	539	2,612	1,709
New Guinea	183	93	147	81
New Zealand	471	265	490	269
Norway	45	27	104	59
Pakistan	192	134	75	57
Peru	175	63	36	27
Philippines	530	282	476	266
Singapore	218	120	343	207
South Africa, Republic of	335	191	163	122
Spain	13	2	--	--
Sweden	26	13	39	20
Switzerland	32	16	114	68
Thailand	214	125	396	268
Trinidad	1	1	2	2
United Kingdom	45	8	15	9
Uruguay	184	99	132	77
Venezuela	223	114	260	168
Other	51	30	122	65
Total	46,319	[2]22,217	41,956	22,938

[1] Includes orthoboric acid and anhydrous boric acid.

[2] Data do not add to total shown because of independent rounding.

Source: U.S. Bureau of the Census.

Table 7.—U.S. imports for consumption of boric acid, by country

Exporting sources	1978		1979	
	Quantity (short tons)	Value[1] (thousands)	Quantity (short tons)	Value[1] (thousands)
Argentina	608	$337	276	$150
Belgium	19	12	159	86
Brazil	--	--	59	30
Canada	40	26	60	47
Chile	332	92	--	--
China:				
Mainland	41	24	--	--
Taiwan	37	25	--	--
France	2,117	1,396	491	280
German Democratic Republic	10	8	--	--
Germany, Federal Republic of	231	140	79	51
India	794	415	--	--
Italy	2,594	1,529	1,761	1,041
Japan	74	44	--	--
Netherlands	314	179	60	33
Romania	417	174	55	26
Spain	1,826	1,074	478	266
Turkey	3,690	1,769	3,658	1,983
United Kingdom	62	41	119	55
U.S.S.R	2,938	1,558	330	164
Yugoslavia	134	78	119	57
Total[2]	16,277	8,921	7,704	4,267

[1] U.S. Customs declared values.
[2] Data may not add to totals shown because of independent rounding.

Source: U.S. Bureau of the Census.

WORLD REVIEW

Argentina.—The Argentine Government enacted a mining law designed to stimulate both foreign and domestic investment.[2] Unlike Chile and Peru, where about half of the national income comes from mining, Argentina annually produces some 80 minerals that represent less than one-half percent of the country's gross national product. The unprecedented legislation to provide tax benefits and investment incentives to mining companies was signed into law in November 1979 after 3 years of controversy over its drafting. The new law could have significant impact on the future growth of the country's boron minerals industry and its major producer, Boroquimica Samicaf, which is foreign-owned.

Chile.—According to a technical study prepared by Saline Processes Inc. (a California consulting firm) on potential production of boric acid and potash from brines of the Atacama Desert, the most viable operation appears to be one capable of producing annually 60,000 tons of boric acid, 850,000 tons of potassium chloride, and up to 275,000 tons of byproduct potassium sulfate.[3]

India.—RTZ Borax, Ltd. of the United Kingdom, a 45% shareholder in Borax Morarji, Ltd. (Bombay), was reportedly selling its interest to the 25% shareholder Dharamsi Morarji of India.[4] Borax Morarji, Ltd., reported that one of its products, granular borax, was becoming increasingly scarce.[5] The company's installed capacity for borax is 18,000 tons per year. Another borax producer, Southern Borax, Ltd., (Madras) also has an annual capacity of 18,000 tons. Past demand for this product has averaged about 13,000 tons per year.

The price of boric acid in India rose 80% in 1979 because of supply difficulties arising from decreased production at a time of increased demand.[6] Demand for boric acid increased from 1,300 tons in 1977 to 3,300 tons in 1979. A supply squeeze of the product occurred after imports of Turkish colemanite ceased, and Borax Morarji, India's sole boric acid producer, could only utilize about two-thirds of its annual production capacity of 3,300 tons. A second boric acid plant of comparable capacity owned by Southern Borax is not yet in operation.

Peru.—Boratos del Peru S.A., a privately owned Peruvian mining concern created in 1971, mines primarily ulexite with lesser quantities of colemanite and tincal at San Juan de Tarucane in Arequipa Province.

Principal markets are the glass and ceramics industries of Peru as well as those of Brazil, Colombia, Bolivia, and Mexico. The company also produces sodium borate derivatives and boric acid.

Turkey.—The Turkish boron minerals industry, led by Etibank, the State Economic Enterprise (SEE) responsible for government boron mining activities, has been second only to the U.S. boron minerals industry in world markets; however, production and exports of colemanite and ulexite were interrupted in 1979 in a chain of events leading to nationalization of the private production of these minerals. The mines where production was interrupted produce about one-third of Turkey's annual production of boron minerals and nearly all of the country's colemanite and ulexite.

In October 1978, the Turkish National Assembly enacted Law No. 2171, which authorizes the Council of Ministers to designate certain SEE's to expropriate any mine operated by the private sector that the Council determines to be essential to the State.[7] The law was intended to increase production or development of key minerals, especially those that serve as raw materials for industry. In November 1978, the Turkish Government published a decree that authorized Etibank to expropriate private boron mineral operations. Boron was chosen because Turkey hopes to take greater advantage of the fact that it is the only area outside the United States where borates are being mined in commercially significant quantities. Prior to 1979, Turkey provided more than one-third of the world's boron supply (in terms of value), although this was primarily in crude ore form. Unfortunately, Turkey's current problems with its economy, fuel supplies, and terrorism,[9] in general; and the boron nationalization, in particular, are expected to reduce the potential for successful implementation in the near term of its mineral development goals.

Although the situation is unclear, the private producers of boron in Turkey are reportedly challenging in the courts the amount of compensation they have been offered.[8] According to the requirements of the law, the value of each mine was to be assessed by an Appraisal Commission within 4 to 6 months of any Council determination. The Appraisal Commission must consider the following factors: Any mineral stocks to be acquired by the State, the mining license, installations, machinery and equipment, land rental, and profits foregone due to breach of contract. The appraisal may include discoverer's fees but may not include the value of mineral reserves, which have long been considered to be Government property. The SEE (in this instance Etibank) is expected to deposit any compensation decided upon in a Turkish national bank within 15 days of an appraisal, at which time the Ministry of Energy and Natural Resources may authorize the SEE to confiscate the mine.

U.S.S.R.—The Soviet Union awarded a $72 million contract for construction of a glass-fiber plant to Woodall-Duckham of England; TBA-Bishop, an Anglo-American concern; and Klockner, the West German group.[10] The plant, which will be located at Polotsk, near Minsk, is scheduled for completion in 1982. The anticipated capacity production of about 132,000 short tons per year would require 25,000 to 40,000 tons of borates, depending on the particular ores or compounds used.

Table 8.—Boron minerals: World production, by country

(Thousand short tons)

Country	1976	1977	1978[p]	1979[e]
Argentina	89	92	75	70
Chile	4	5	29	30
China, mainland[e]	25	30	30	30
Peru[e]	10	20	22	30
Turkey	1,005	1,211	1,455	1,000
United States[1]	1,246	1,469	1,554	1,590
U.S.S.R.[e]	200	200	220	220
World total[2]	2,600	3,000	3,400	2,900

[p] Preliminary. [e] Estimate.

[1] Minerals and compounds sold or used by producers.

[2] Data may not add to totals shown because of independent rounding.

TECHNOLOGY

The 1979 Nobel Prize in Chemistry was shared by two organic chemists, one of which was Herbert C. Brown, who received the award for his applications of boron compounds to synthetic organic chemistry.[11] Professor Brown, of Purdue University, discovered the hydroboration reaction of diborane with olefins, which has made organoborane compounds available as chemical intermediates. These versatile reagents find application in the manufacture of cortisone and other drugs as well as in a new class of pesticides. But most important for the future, they introduce an exponential increase in the number of pathways available to a synthetic goal and suggest whole new areas of organometallic chemistry to explore. Earlier in his career, Professor Brown developed the alkali metal borohydrides that industrial organic chemists have found to be ideal as reducing agents.

The Bureau of Mines published a Report of Investigations on work to determine and compare the viscosity-temperature profiles of basic oxygen furnace (BOF) slags fluidized with fluorspar, colemanite (a calcium borate mineral), and fused (anhydrous) boric acid.[12] Fluorspar is commonly used as a flux in the BOF steelmaking process; however, the potential need to find a fluorspar substitute has resulted from the steadily increasing U.S. dependence on imported fluorspar and problems of air pollution from volatolized fluorine compounds escaping during the BOF process. The relative absence of air pollution problems and the comparable fluxing capabilities of boron oxide systems make boron materials a promising substitute.

The Bureau of Mines also published a Report of Investigations on methods for electrodepositing titanium diboride coatings on other materials in order to provide improved corrosion- and erosion-resistant properties.[13] Research leading to a patented process was conducted at the Avondale Research Center as part of the Bureau's goal to minimize requirements for minerals through conservation and substitution.

Other work on coatings is underway at Batelle-Columbus Laboratories, where researchers participating in an experimental program have successfully evaporated a boron alloy in the presence of ammonia gas and deposited (at relatively low pressure and temperature) a coating containing 20% cubic boron nitride, 25% hexagonal boron nitride, and 55% iron boride onto a stainless-steel substrate.[14] Because the deposited coating's cubic crystalline boron nitride constituent gives the coating high hardness and good abrasion resistance, its potential for use on cutting tools is expected to be particularly attractive. For example, higher cutting rates would be possible, compared with those of commonly used tungsten carbide. Also, because a coolant could be used with boron-nitride-coated tools, better surface finishes could be obtained than when using dry tools that have alumina-ceramic coatings with a titanium-compound additive.

Industrial, university, and U.S. Government research involving boron compounds ranged from solar heating and composite fibers to medicine, communications, and storage of nuclear wastes. Owens-Illinois, Inc., began marketing evacuated-tube solar energy collectors, which are composed of three concentric borosilicate glass cylinders.[15] Although evacuated-tube collectors are more expensive than conventional flat-plate rooftop collectors, they can capture twice as much solar energy per unit area. Owens-Illinois expects its collector to penetrate the industrial process-heat market and eventually make solar airconditioning commercially attractive.

Aided by Federal grants, the Massachusetts Institute of Technology (MIT), collaborated with private firms to develop a passive solar heating system based on a chemical heat sink of borax decahydrate, anhydrous sodium sulfate, common salt, and water.[16] The chemical core, which is encapsulated in precast polymer concrete ceiling tiles, absorbs reflected solar radiation coming through windows having a Southern exposure during the day, and releases the captured energy during the night. Energy storage and release occur through cycles of hydration and dehydration of the sodium sulfate. The borax constituent acts as a nucleating agent to support uniform crystallization. MIT's experimental system has maintained a room temperature that varies from a high of 73°F in daytime to a low of 65°F at night.

Boron and other exotic reinforcements, once limited to application in the aerospace industry, are being used in more mundane products. Advanced composites of fibrous boron, graphite, glass, aramid, and other strong, lightweight materials have become important components in a variety of sports equipment, including skis, boats, bicycles, golf clubs, tennis rackets, and bows and arrows.[17] The latest developments in composites are various combinations of continuous or chopped filaments in a common thermo-plastic or thermoset resin matrix.[18] Described as hybrid composites, these materials have unique features that can be used to meet diverse and competing design requirements in a more cost-effective way than either advanced or conventional composites. They can be used advantageously in products ranging from automobiles and aerospace hardware to sporting goods and textile machinery.

Chemists at Duke University have synthesized boron compounds that appear to show considerable promise as therapeutic agents.[19] In preliminary animal tests, boron containing amino acid analogs (in which a boron atom has replaced a carbon atom) produced beneficial effects in treating arthritis, high blood-cholesterol levels, and several types of malignant tumors. No evidence of toxic effects has appeared in any of the animal tests. This is an important factor if the compounds are to find eventual use as drugs for humans.

Researchers in the fiber optics program at Bell Labs, Murray Hill, N.J., published their method for preparing high-purity sodium borosilicate glass-fiber for use in optical communications systems.[20] Test results indicated that the multicomponent glass (45% SiO_2, 35% B_2O_3, and 20% Na_2O) exhibited the required quality of low spectral loss. Made from boric acid, soda ash, and silica, the glass offers the advantage over conventional high-silica optical fibers of lower melting and fiber-drawing temperatures.

The boron atom's ability to capture radioactive emissions is being applied in research to contain nuclear wastes. The Abrasives Systems Group of Carborundum Co. has formed a team to develop and market boron carbide shielding for handling, transporting, and containing spent fuel elements from nuclear power plants.[21] The U.S. Department of Energy (DOE) is studying the efficacy of incorporating radioactive wastes into a special zinc borosilicate glass.[22] For more than 20 years, DOE and its predecessor agencies have assumed that long-term storage of these wastes could best be achieved by encapsulating them in glass and storing them in underground salt domes. However, controversy has arisen from new findings of researchers in the United States, Australia, and Sweden.[23] According to their reports, radioactive wastes can leak from their glass containers under attack by heat, water, and elevated pressures found deep inside the earth.

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Bromine

By Sandra T. Absalom[1]

Elemental bromine sold or used by U.S. producers returned to the rising trend in annual growth experienced prior to 1977. Expanding foreign markets and the changing composition of the domestic market were the important factors affecting U.S. production, which was centered in the State of Arkansas, with additional production in Michigan.

The primary manufacturers of brominated compounds operated plants in Arkansas, Michigan, and Texas. One of them, however, discontinued its Michigan operation in 1978. Primary producers' sales of all types of bromine compounds increased, although demand for the industry's major product, ethylene dibromide, as a leaded-gasoline additive continued to fall with the Government-regulated decline in use of leaded gasoline. As laboratory tests were completed on several potentially harmful bromine compounds, Federal regulatory agencies acted in accordance with significant test results.

Legislation and Government Programs.—The Interagency Regulatory Liaison Group (IRLG), which is composed of Federal regulatory agencies, took an important step to coordinate the attack on potentially hazardous chemicals and other substances. The original member agencies (Consumer Product Safety Commission, Environmental Protection Agency, Federal Drug Administration, and Occupational Safety and Health Administration) formed IRLG in 1977 to share individual research, data, and analyses; avoid duplicative regulations; and attempt to set consistent standards to control hazards. In 1978, the group released a list of 24 compounds, or categories of substances, targeted for special attention.[2] Three brominated organic compounds were included on the list: Dibromochloropropane, an insecticide; ethylene dibromide, a gasoline additive and pesticide; and polybrominated biphenyls, the industrial fire retardant that in 1973 was accidentally mixed with cattle feed in Michigan. In 1979, IRLG drafted guidelines for uniform testing among Federal agencies for five ill effects to humans that could be caused by potentially harmful chemicals.[3] The IRLG goal is to develop a single set of tests to replace the different tests the agencies now use to determine the same ill effects. These effects cover acute inhalation, birth defects, acute oral toxicity, acute eye irritation, and acute skin effects.

The Occupational Safety and Health Administration (OSHA) issued final rules in 1978 for workplace exposure to dibromochloropropane (DBCP).[4] The compound has been linked to worker sterility in several chemical plants and also was labeled a possible carcinogen by the National Cancer Institute (NCI).[5] The final exposure limit of 1 part per billion (ppb) averaged over an 8-hour workday is 10 times stricter than the 10-ppb emergency temporary standard ordered by OSHA in 1977. The final standard also prohibits eye and skin contact with the agricultural insecticide. Following the recommendation in 1979 of an administrative law judge, the Environmental Protection Agency (EPA) banned all applications of DBCP except in Hawaiian pineapple groves.[6] Other agricultural uses of DBCP will be suspended indefinitely while further research is conducted.

EPA issued its final rule extending the compliance deadline for reducing the amount of lead antiknock compounds in gasoline.[7] The rule delays the agency's deadline for a 0.5-gram-per-gallon limit on lead in gasoline from October 1979 to October 1980; however, refiners must comply with certain requirements on gasoline production to qualify for the extension. Increased use of low-lead and unleaded gasoline will reduce domestic consumption of ethylene dibromide (EDB), which is used primarily as a scavenger for lead added to gasoline in antiknock compounds.

OSHA reportedly was considering making the workplace standard for EDB more stringent, and EPA was considering restricting its use as a pesticide.[8] These proposals followed the announcement by NCI that EDB proved to be a potent carcinogen in ingestion tests conducted on rats and mice.[9] The Dow Chemical Co. and Ethyl Corp., producers of EDB, disputed the validity of the test procedures and the extrapolation of results to humans. They contend that actual industrial experience does not agree with the laboratory findings.

NCI reported another bromine chemical to be an animal carcinogen following 130-week tests on rats and mice.[10] The compound was tris (2,3-dibromopropyl) phosphate, the flame retardant that the Consumer Product Safety Commission (CPSC) banned in 1977 for use in children's sleepwear. The CPSC was involved in several actions in 1978 concerning tris: It abandoned its attempt to force eight manufacturers of tris-treated products to repurchase the millions of dollars of these goods they had sold.[11] CPSC also ruled that it has the authority to ban exports of tris-treated apparel.[12] This authority, however, was expected to be challenged in the courts. Following Congressional passage of a bill to provide government payments to clothing manufacturers, retailers, and others in the apparel industry that had incurred losses as a result of the tris ban, President Carter pocket vetoed the legislation.[13] Among several reasons given for the veto, the President stated that the law would have set an "unwise precedent" to pay industry's losses when a product is used to meet a regulatory standard and that product is later judged to be hazardous.

OSHA reportedly was contemplating regulation of workplace exposure to the chemical vinyl bromide, based on reports that rats had developed cancer following low-level exposure.[14]

The State of Michigan issued a report on a special study of the health effects of small amounts of polybrominated biphenyls (PBB) in the bodies of Michigan residents.[15] Although the State will continue monitoring the health of the general population for a 10-year period, the initial study concluded that low-level PBB contamination of an estimated 90% of residents, which resulted from accidental introduction of the chemical into the food chain in 1973, has caused no adverse health effects.

DOMESTIC PRODUCTION

Six companies operated nine plants to extract bromine from brines in Arkansas and Michigan. The producers of elemental bromine were also the major manufacturers of bromine compounds, with two additional plants, one in Texas and one in Michigan; however, the St. Louis, Mich., plant of Velsicol Chemical Corp. was closed on September 1, 1978.[16] The September deadline was a result of a 1976 settlement made with the State of Michigan following pollution problems involving the plant and its products. Negotiations to sell the plant before the deadline failed when certain conditions specified by the State Department of Natural Resources could not be resolved between Velsicol, the buyers, and the State. In December, Velsicol announced a $3 million program for its El Dorado, Ark., bromine production plant to enable the plant to meet current and future environmental regulations.[17] The program was scheduled to be completed in 1979.

Table 1.—Elemental bromine sold as such or used in the preparation of bromine compounds by primary U.S. producers

(Million pounds and million dollars)

	1977		1978		1979p	
	Quantity	Value	Quantity	Value	Quantity	Value
Sold	59.0	12.8	53.2	11.3	59	13
Used	374.8	86.9	393.4	88.7	443	102
Total	433.8	99.7	[1]446.5	100.0	502	115

pPreliminary.

[1] Data do not add to total shown because of independent rounding.

Table 2.—Bromine compounds sold by primary U.S. producers

(Million pounds and million dollars)

	1977			1978			1979[p]		
	Quantity			Quantity			Quantity		
	Gross weight	Bromine content	Value	Gross weight	Bromine content	Value	Gross weight	Bromine content	Value
Ethylene dibromide	279.6	237.8	75.1	259.2	220.5	63.9	288	245	67
Methyl bromide	32.9	27.7	15.7	42.6	35.8	20.9	55	46	28
Other compounds[1]	125.1	86.7	99.2	170.3	119.5	129.5	228	163	171
Total[2]	437.6	352.2	190.0	472.1	375.8	214.4	571	454	266

[p] Preliminary.

[1] Includes hydrobromic acid, tetrabromobisphenol-A, ethyl, calcium, ammonium, sodium, potassium, and other bromides, plus some methyl bromide exports.

[2] Data may not add to totals shown because of independent rounding.

Table 3.—Bromine-producing plants in the United States

State and company	County	Plant	Production source
Arkansas:			
Arkansas Chemicals, Inc	Union	El Dorado	Well brines.
The Dow Chemical Co	Columbia	Magnolia	Do.
Ethyl Corp	do	do	Do.
Great Lakes Chemical Corp	Union	El Dorado	Do.
Do	do	Marysville	Do.
Velsicol Chemical Corp	do	El Dorado	Do.
Michigan:			
The Dow Chemical Co	Mason	Ludington	Do.
Do	Midland	Midland	Do.
Morton Chemical Co	Manistee	Manistee	Do.

CONSUMPTION AND USES

Although demand increased for bromine compounds in general, demand declined for EDB, which has traditionally been the most important bromine chemical, as a constituent in gasoline. This was primarily because reduced requirements for lead in gasoline necessitated a corresponding reduction in lead-scavenging additives. Use of EDB as an insecticide and soil fumigant continued to grow, however, owing to its substitution for another bromine compound (1,2-dibromo-3-chloropropane or DBCP) after EPA banned the use of DBCP in certain agricultural applications.

In view of the decline in traditional markets for some bromine chemicals, producers sought to satisfy growing markets for others, such as methyl bromide, another agricultural fumigant. Rising sales of a variety of bromine compounds in the "other compounds" category were attributed in part to growing demand for certain flame retardants and for calcium bromide.

Calcium bromide is used by the oil- and gas-well drilling industry for high-density, solids-free completion, packer, and workover fluids. As a result of rapid growth in oil industry demand, three of the producers of elemental bromine and its compounds announced plans to expand capacity in 1979 for producing calcium bromide solutions.[18] The Dow Chemical Co., which in 1978 increased capacity at Midland, Mich., to 84 million pounds, announced a further incremental increase that would bring calcium bromide capacity to 120 million pounds per year. Velsicol Chemical Corp.'s plants at Beaumont, Tex., and El Dorado, Ark., will have combined annual capacity of about 13 million pounds. Another plant at El Dorado, Ark., that of Great Lakes Chemical Corp., was expected to increase its annual capacity to almost 100 million pounds.

Expanding in another direction, Great Lakes purchased in 1978 Tesco Chemicals, Inc., of Atlanta, Ga., a manufacturer and distributor of swimming pool sanitation chemicals and dispensing devices.[19] The acquisition was expected to enhance the growth of Great Lakes' bromine-based swimming pool products, which the firm purchased in 1977. In 1978 Great Lakes also acquired WIL Research Laboratories of Cincinnati, Ohio. WIL is an independent animal testing laboratory with clients in the pharmaceutical, food, cosmetic, and chemical industries, as well as government agencies.

The Dow Chemical Co. announced plans to construct a 30-million-pound-per-year facility to produce bromine chloride for use in disinfecting municipal and industrial waste water.[illegible] The facility, which is to be located in Houston, Tex., is expected to come onstream in 1980 (see Technology).

PRICES

The industry-wide base price for elemental bromine in bulk reached 28 cents per pound by yearend 1979; however, discount pricing was prevalent. The average price of bulk elemental bromine, f.o.b. plant, reported by U.S. producers was 21.24 cents per pound in 1978 and 22.03 cents per pound in 1979. Quoted yearend prices for elemental bromine and selected compounds follow.

Table 4.—Prices of elemental bromine and selected compounds

Product	Value per pound (cents) December 31	
	1978	1979
Bromine, purified:		
Carlots, truckloads, delivered	75	75
Drums, carlots, truckloads, delivered east of the Rocky Mountains[1]	55-62	55-69
Bulk tank car, tank trucks (45,000-pound minimum), delivered east of the Rocky Mountains[1]	25-30	26.5-28
Ammonium bromide, national formulary (N.F.), granular, drums, carlots, truckloads, freight equalized	74	74
Bromochloromethane, drums, carlots, f.o.b. Midland, Mich	98	98
Bromoform, pharmaceutical grade, 5-gallon drums, f.o.b. works	270	270
Ethyl bromide, technical, 98%, drums, carlots, freight allowed, East	61.5	61.5
Ethylene dibromide, drums, carlots, freight equalized	37	37
Hydrobromic acid, 48%, drums, carlots, truckloads, f.o.b. works	39-41	39-41
Hydrogen bromide, anhydrous, cylinders, extra, 30,000 pounds, f.o.b. works	65	65
Methyl bromide, distilled, tanks, 140,000-pound minimum, freight allowed	41	41
Potassium bromate, granular, powdered, 200-pound drums, carlots, f.o.b. works	106	106
Potassium bromide, N.F., granular, drums, carlots, f.o.b. works	67	67
Sodium bromide, 99%, granular, 400-pound drums, freight, f.o.b. works	65	65

[1] Delivered prices for drums and bulk shipped west of the Rockies, 1 cent per pound higher. Bulk truck prices 1 cent per pound higher for 30,000-pound minimum and 2 cents per pound higher for 15,000-pound minimum. Price f.o.b. Midland and Ludington, Mich., freight equalized, 1 cent per pound lower.

Sources: Chemical Marketing Reporter. Current Prices of Chemicals and Related Materials. V. 215, No. 1, Jan. 1, 1979, pp. 46-55, and V. 216, No. 27, Dec. 31, 1979, pp. 26-35.

FOREIGN TRADE

Increasing producer exports of elemental bromine and bromine contained in compounds (table 5) were major factors in regaining the sales level that existed prior to Federal restrictions on domestic uses.

In 1978, about 82% of imported bromine and bromine compounds (table 6), which amounted to less than 1% of domestic consumption, were shipped from Israel, and 11% from the Netherlands; however, in 1979 about 99% of imports were from Israel. Other bromine compounds imported by the United States are not easily identified because they are classified in multiproduct categories.

Table 5.—U.S. exports of bromine and bromine compounds by primary producers

(Thousand pounds and thousand dollars)

Year	Elemental bromine		Bromine compounds		
	Quantity	Value	Gross weight	Contained bromine	Value
1976	4,400	900	74,100	62,600	29,200
1977	5,400	1,100	64,400	54,100	27,300
1978	6,400	1,300	106,000	87,900	38,500
1979[p]	10,100	2,100	98,300	83,100	37,500

[p] Preliminary.

Table 6.—U.S. imports of bromine and bromine compounds

(Thousand pounds and thousand dollars)

	1977		1978		1979	
	Quantity	Value	Quantity	Value	Quantity	Value
Elemental bromine	517	102	669	102	34	5
Potassium bromide	89	56	119	84	794	586
Sodium bromide	106	60	320	175	2,190	1,056
Ethylene dibromide	79	22	589	102	193	33

Source: U.S. Bureau of the Census.

WORLD REVIEW

The United States, as world leader in bromine production and consumption, produces annually about two-thirds of the world total. Other principal bromine-producing nations include, in decreasing order, Israel, the United Kingdom, France, the U.S.S.R., and Japan.

China, mainland.—The Ginghai Salt Lake Institute of the Chinese Academy of Sciences completed an evaluation of the mineral resource potential of the Tibetan Plateau.[21] Following a general survey of the multitude of salt lakes in the region, more than 50 in northern and western Tibet were examined in more detail. The brines contain high percentages of bromine, sodium, potassium, boron, magnesium, lithium, rubidium, cesium, uranium and thorium. China produces large tonnages of salt by evaporation of sea and inland brines, as well as by underground mining, and also already obtains bromine, borax, iodine, lithium, potash, sodium sulfates, and other minerals from salt lakes at Chaerhan, Yuncheng, and elsewhere.

Israel.—The Customs Service, U.S. Department of the Treasury, made a final countervailing duty determination involving manufacturers and/or exporters of Israeli bromine and brominated compounds.[22] The final determination reversed the preliminary determination in which the Israeli Government was found to have given two companies benefits considered to be bounties or grants under U.S. law. Although the final results of the Customs investigation confirmed that the two firms, Dead Sea Bromine Co., Ltd. and Bromine Compounds, Ltd., had indeed received partial rebates of property taxes and other kinds of aid, these were considered to be minimal and, therefore, not legally classified as bounties or subsidies.

The Israeli Government was reportedly preparing to take the first step to change the nation's economic system from one of socialism to free-enterprise by either selling outright, or offering shares in as many as 160 Government-owned or Government-controlled companies.[23] One of the largest of these concerns, Israel Chemicals, Ltd. (ICL), is the parent organization of numerous natural resource development and inorganic chemical firms, including Dead Sea Bromine and Bromine Compounds. Ongoing expansion of capacity for producing bromine compounds at the new industrial park at Ramat Hovav may reach 100,000 tons per year by 1984.[24] Production of calcium bromide is part of the expansion plan (see Technology).

Japan.—The Ministry of Health and

Welfare ban of the use of tris (2,3-dibromopropyl) phosphate as a fire retardant in clothes, soft furnishings, paints, household adhesives, and shoe polish went into effect on November 1, 1978.[25] The ruling was aimed at possible imports of consumer goods containing tris since the compound itself is not made in Japan.

Jordan.—The Arab Potash Co., owned by the Jordanian Government (51%), the Arab Mining Co. (44%), and the Libyan Government (5%), has reportedly raised $231 million to finance the Dead Sea potash project.[26] In addition, plans were announced for expanding the project to construction of facilities to produce bromine and refractory magnesia. The bromine project, which is expected to cost $60 million, will employ U.S. technology provided by Great Lakes Chemical Corp. (25% interest). The proposed annual production of 33,000 short tons of bromine would have potential to rival in world markets the growing importance of Israel's Dead Sea Bromine operation.[27]

Netherlands.—Broomchemie, the bromine compounds producer that opened a new plant at Terneuzen in 1977, was accused of failure to comply with agreed upon safety regulations.[28] Broomchemie is the production company of Eurobroom in The Hague, which is a subsidiary of the Dead Sea Bromine Group of Israel. Elemental bromine from Israel serves as the raw material for manufacture at Terneuzen of sodium, potassium, and ammonium bromides, carbon tetrabromide, and other bromine products. Reports that plant workers were experiencing symptoms caused by high bromide concentrations in the workplace environment prompted a governmental inquiry that resulted in a fine of $1,200.[29] The environmental inspector's recommendation for closing the tetrabromobisphenol-A (TBBA) plant was overruled by provincial authorities after Broomchemie installed new environmental control equipment.[30]

United Kingdom.—Following the lead of the United States and other countries, the United Kingdom banned the supply of tris-treated nightwear for children.[31] The ban will go into effect throughout the European Community on January 1, 1980.[32]

Table 7.—Bromine: World production, by country

(Thousand pounds)

Country[1]	1976	1977	1978[p]	1979[e]
France	33,466	34,326	[e]35,000	35,000
Germany, Federal Republic of	9,158	8,236	8,583	8,600
India[e]	600	620	660	600
Israel	46,100	69,450	76,170	100,000
Italy	[r]1,230	[e]1,300	[e]1,300	1,300
Japan[e]	26,500	26,500	26,500	26,000
Spain[e]	[r]900	900	900	900
United Kingdom	[r]65,928	54,500	55,000	55,000
United States[2]	[r]468,000	433,900	446,500	502,000
U.S.S.R.[e]	30,000	33,000	33,000	33,000
Total[3]	682,000	663,000	684,000	762,000

[e] Estimate. [p] Preliminary. [r] Revised.

[1] In addition to the countries listed, several other nations produce bromine, but output data are not reported and available general information is inadequate for formulation of reliable estimates of output levels.

[2] Sold or used by producers.

[3] Data may not add to totals shown because of independent rounding.

TECHNOLOGY

A new process for producing calcium bromide directly has been developed by TAMI, the research arm of Israel Chemicals Ltd.[33] TAMI developers say the method uses less energy and is more economical than conventional processes that must produce elemental bromine first. The direct route takes advantage of the high bromine content (up to 10,000 parts per million) of the Dead Sea. Calcium bromide is selectively extracted out of sea brine by means of an undisclosed solvent, which is subsequently removed, and the calcium bromide is concentrated to 52% by evaporation. The compound can be used to make other bromides, and is finding increased usage in oil-well drilling muds.

Exxon Research and Engineering demonstrated a laboratory prototype of a zinc-bromine battery at the Electric Vehicle

Expo II in Philadelphia.[34] The battery, being developed for use in electric vehicles and for utility load leveling, has a projected energy density two to three times that of conventional lead-acid batteries, or 35 watt-hours per pound. Design estimates place the cost of the battery at $30 per kilowatt-hour. Among the advantages of the prototype (a 6-volt, 80-ampere-hour system that has been under development for 3 years) are operation at ordinary temperatures and low-cost components.

Research into the structure and function of hemoglobin, the oxygen-carrying molecule in blood, and into what goes wrong with hemoglobin in sickle cell anemia patients, has led to investigation of several types of chemicals that show potential to treat the disease.[35] A research group at Northwestern University is exploring the use of a brominated aspirin derivative (acetyl-3,5-dibromosalicylic acid) that can enter red blood cells to react with the hemoglobin inside, and thereby prevent the cell deformation known as sickling. Although toxicity studies have not yet been conducted, it is generally believed that derivatives of well-known drugs such as aspirin stand a good chance of being approved for therapeutic use in humans.

An experimental drug therapy for workers poisoned by the pesticide Kepone appears to have potential for detoxifying the systems of persons afflicted with dangerous levels of other halogenated hydrocarbons.[36] Successful preliminary research at Virginia Medical College using cholestyramine, a bulky anion-exchange resin, could possibly be expanded to detoxification studies of such potential carcinogens as PBB, polychlorinated biphenyls (PCB), mirex, aldrin, dieldrin, and DDT. Future research would include studies of the mechanism of halogenated hydrocarbon excretion from the body, and the safety of using cholestyramine and similar agents for eliminating these compounds.

Field trials at two waste-water treatment plants have convinced the Dow Chemical Co. that bromine chloride has greater efficacy in killing bacteria and viruses than chlorine.[37] Although more expensive than chlorine, bromine chloride offers the advantages of use at lower vapor pressures, shorter retention time, and avoidance of formation of chemical compounds that may be toxic to fish.

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Cadmium

By John M. Lucas[1]

Domestic production of cadmium metal in 1978 declined 17% from the production level of 1977, and output in 1979 was 4% higher than in 1978. Shipments of cadmium in both years increased over those of 1977 but failed to approach the volume reported during 1976.

Six companies operating seven plants produced all of the domestic cadmium during 1978. An eighth plant, the new electrolytic zinc plant of Jersey Miniere Zinc Co., came onstream at yearend 1978 and began production of cadmium in 1979. In December 1979, St. Joe Zinc Co. permanently closed its zinc smelter at Monaca, Pa., where byproduct cadmium was also produced. Canada continued as the major source of imported zinc concentrates from which cadmium was extracted as a byproduct. The producer price of cadmium, in a range of $2.25 to $2.50 per pound, remained unchanged throughout 1978. By the close of 1979, the producer price ranged from $2.50 to $3 per pound.

Legislation and Government Programs.—In 1978, the Environmental Protection Agency (EPA) proposed limits on cadmium in specific categories of solid waste destined for agricultural application on lands used for the production of food-chain crops or meats for human consumption.[2]

On July 11, 1978, EPA issued final effluent limitation guidelines for existing facilities operating within the ore mining and dressing point-source category. The regulation defined limits on cadmium and other substances discharged in effluents originating from specified types of ore milling and concentrating operations.[3]

The proposed approach for implementation of the Toxic Substances Control Act of 1976 was published by EPA on October 26, 1978. EPA proposed to regulate the manufacture, distribution, use, or dispersal of certain substances, including cadmium and any of its compounds.[4]

In December 1978, a quality-control standard suggested by the decorated glass tumbler industry was, with some modification, endorsed by a Federal interagency regulatory task force consisting of EPA, the Food and Drug Administration, and the Consumer Product Safety Commission. Industrial compliance with the voluntary quality-control program, which defines the application of cadmium and lead, assures no significant risk to decorated glassware users.[5]

The occupational health and environmental aspects of cadmium and the requirements for additional research were discussed at the 1978 International Conference on Cadmium, cosponsored by the National Institute of Environmental Health Sciences of the U.S. Department of Health, Education, and Welfare and the Karolinska Institute, Stockholm, Sweden.

Effective October 1979, EPA promulgated final regulations on the concentration of cadmium and other pollutants contained in process waste water from plating operations and destined for publicly owned treatment works. The deadline for compliance with this regulation was set for October 12, 1982.[6]

Under the provisions of the Water Pollution Control Loan Program, the Small Business Administration may grant direct loans or loan guarantees of up to 90% for terms of up to 30 years to small electroplaters certified to have been adversely affected by EPA's proposed pretreatment standards for the electroplating point-source category.

In September 1979, EPA issued interim final criteria for the classification and application of cadmium-bearing solid waste to land used for the production of food-chain crops.[7]

The national stockpile goal for cadmium of 11,204 metric tons remained unchanged through 1979.[8] The total inventory at yearend 1979 was 2,871 tons, with no acquisitions or releases in 1978 or 1979.

Table 1.—Salient cadmium statistics

	1975	1976	1977	1978	1979
United States:					
Production[1] metric tons	1,990	2,047	1,999	1,653	1,715
Shipments by producers[2] do	742	2,707	1,837	1,957	2,370
Value thousands	$4,166	$10,498	$7,072	$5,906	$9,498
Exports metric tons	180	229	107	326	211
Imports for consumption, metal do	2,375	3,094	2,332	2,881	2,572
Apparent consumption do	3,055	5,381	3,818	4,510	4,817
Price: Average per pound[3]	$3.36	$2.66	$2.96	$2.45	$2.76
World: Production metric tons	15,234	16,773	17,935	16,765	18,280

[1] Primary and secondary cadmium metal. Includes equivalent metal content of cadmium sponge used directly in production of compounds.

[2] Includes metal consumed at producer plants.

[3] Average quoted price for cadmium sticks and balls in lots of 1 to 5 tons.

DOMESTIC PRODUCTION

Domestic cadmium metal production in 1979 increased slightly over that of 1978; however, production during both years failed to reach levels achieved during 1976 and 1977.

In mid-December 1979, St. Joe Zinc Co., a major producer of zinc and byproduct cadmium, announced the permanent closure of its electrothermic zinc smelter at Monaca, Pa. The company was studying the feasibility of replacing the Monaca facility with a new electrolytic smelter at an unspecified location.

In 1978 recovery of cadmium metal averaged just over 4 kilograms per ton of slab zinc produced in domestic smelters, compared with an average of 4.8 kilograms recovered between 1973 and 1977. Recovery of cadmium in domestic smelters between 1964 and 1973 ranged from 4.2 to 6.3 kilograms per ton of slab zinc.

During 1979 production of cadmium compounds other than cadmium sulfide (cadmium content), which includes both electroplating salts and cadmium oxide, increased over that of 1978. The quantity of cadmium produced under this category has, with a few exceptions, registered a steady increase in recent years. Production in 1979, for example, was 30 times greater than that of 1971. Cadmium oxide was produced at two primary-metal-producing plants. Data on cadmium oxide production are not published to avoid disclosing company proprietary data. The production of cadmium sulfide (including cadmium sulfoselenide and lithopone) during 1979 registered a significant increase over 1978 production.

Table 2.— Primary cadmium producers in the United States in 1978 and 1979

Company	Plant location
Amax Zinc Co., Inc	Sauget, Ill.
ASARCO Incorporated	Corpus Christi, Tex., and Denver, Colo.
The Bunker Hill Co	Kellogg, Idaho
Jersey Miniere Zinc Co	Clarksville, Tenn.
National Zinc Co	Bartlesville, Okla.
The New Jersey Zinc Co	Palmerton, Pa.
St. Joe Zinc Co.[1]	Monaca, Pa.

[1] Closed permanently Dec. 21, 1979.

Table 3.—U.S. production of cadmium compounds other than cadmium sulfide[1]

(Metric tons)

Year	Quantity (cadmium content)
1975	202
1976	990
1977	695
1978	708
1979	912

[1] Includes plating salts and oxide.

Table 4.—Cadmium sulfide[1] produced in the United States

(Metric tons)

Year	Quantity (cadmium content)
1975	895
1976	729
1977	639
1978	698
1979	1,494

[1] Includes cadmium lithopone and cadmium sulfoselenide.

CONSUMPTION AND USES

The apparent consumption of cadmium in 1978 was 18% greater than that of 1977, and in 1979 was 7% greater than that of 1978. Though actual consumption data are not gathered by the Bureau of Mines, the distribution of apparent consumption during

1978 and 1979 was estimated for the following principal use categories: Transportation, coating and plating, batteries, pigments, plastics and synthetic products, and alloys and other uses. Cadmium consumed directly in the transportation category, which included cadmium from each of the remaining end-use categories, accounted for an estimated 17% of the total demand. Electrically or mechanically plated hardware consumed an estimated 34%, while cadmium used in nickel-cadmium, silver-cadmium, and mercury-cadmium batteries was estimated to have consumed 22%. Cadmium used in pigments, plastics and synthetic products, and the alloys-and-other category was estimated to have accounted for 13%, 11%, and 3%, respectively of the total apparent consumption.

Table 5.—Supply and apparent consumption of cadmium

(Metric tons)

	1977	1978	1979
Stocks, Jan. 1	2,165	2,571	2,269
Production	1,999	1,653	1,715
Imports, metal	2,332	2,881	2,572
Total supply	6,496	7,105	6,556
Exports	107	326	211
Stocks, Dec. 31	[r]2,571	2,269	1,528
Apparent consumption[1]	[r]3,818	4,510	4,817

[r] Revised.

[1] Total supply minus exports and yearend stocks.

STOCKS

Inventories of cadmium metal held by metal producers and cadmium metal and cadmium in compounds held by compound manufacturers generally declined from yearend 1977 to yearend 1979; conversely, the quantity of both cadmium metal and cadmium in compounds held by merchants and distributors of these products increased during the same period.

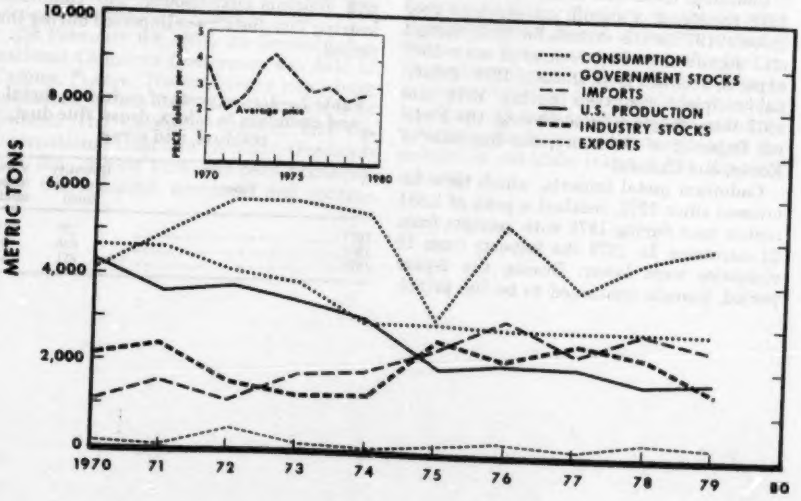

Figure 1.—Trends in production, consumption, yearend stocks, exports, imports, and average price of cadmium metal in the United States.

Table 6.—Industry stocks, December 31

(Metric tons)

	1977		1978		1979	
	Cadmium metal	Cadmium in compounds	Cadmium metal	Cadmium in compounds	Cadmium metal	Cadmium in compounds
Metal producers	^{r}1,452	W	1,152	W	506	W
Compound manufacturers	72	^{r}774	^{r}45	^{r}758	52	609
Distributors	255	18	^{r}296	^{r}18	341	20
Total	^{r}1,779	^{r}792	^{r}1,493	^{r}776	899	629

^{r}Revised. W Withheld to avoid disclosing company proprietary data; included with "Compound manufacturers."

PRICES

The producer price range of $2.25 to $2.50 per pound for cadmium metal established in December 1977 remained unchanged throughout 1978. Dealer prices, which were $1.85 to $1.95 per pound in early 1978, trended generally upward throughout the year, closing at $2.13 to $2.23.

During 1979 the producer price for cadmium metal rose to $2.75 to $3.25 per pound by April, settled at $2.50 per pound from August to December, and closed the year at $2.50 to $3 per pound. Dealer prices during the year followed a similar upward pattern, ending at $2.85 to $2.95 per pound.

The announcement in November 1979, that St. Joe Zinc Co. would close its smelter reportedly contributed somewhat to the upward price movement exhibited by both producer and dealer prices toward yearend.

FOREIGN TRADE

Cadmium metal and scrap exports during 1978 registered a significant increase over those of 1977, while exports for 1979, though still significant when compared with 1977 exports, declined from those of 1978. Principal recipient countries during 1978 and 1979 were Belgium-Luxembourg, the Federal Republic of Germany, the Republic of Korea, and Canada.

Cadmium metal imports, which have increased since 1972, reached a peak of 2,881 metric tons during 1978 with receipts from 21 countries. In 1979 the imports from 19 countries were lower. During the 2-year period, Canada continued to be the principal supplier, followed by Australia, Mexico, and Belgium-Luxembourg. No cadmium-bearing flue dusts were imported during the period.

Table 7.—U.S. exports of cadmium metal and cadmium in alloys, dross, flue dust, residues, and scrap

Year	Quantity (metric tons)	Value (thousands)
1977	107	$316
1978	326	864
1979	211	550

Table 8.—U.S. imports for consumption[1] of cadmium metal, by country

Country	1978		1979	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Algeria	10	$49	--	--
Australia	406	1,736	319	$1,716
Austria	5	22	--	--
Belgium-Luxembourg	292	1,274	237	1,356
Canada[2]	667	3,497	695	3,709
Denmark	--	--	5	23
Finland	82	390	128	710
France	56	246	100	537
Germany, Federal Republic of	91	397	20	114
India	8	34	--	--
Italy	6	23	--	--
Japan	4	18	10	45
Korea, Republic of	242	927	200	1,020
Mexico	436	1,896	288	1,579
Netherlands	79	333	103	574
Norway	6	26	107	528
Peru	130	550	142	762
Portugal	--	--	8	36
Spain	162	629	59	272
Sweden[2]	48	210	23	135
United Kingdom[2]	16	61	23	153
Yugoslavia[2]	100	407	80	404
Zaire	35	136	25	167
Total	2,881	12,861	2,572	13,840

[1] General imports and imports for consumption were the same in 1978 and 1979.
[2] Includes waste and scrap (gross weight).

WORLD REVIEW

The Korean Zinc Co. dedicated its new electrolytic zinc plant at Onsan in the Republic of Korea in November 1978. The plant has an annual capacity of 50,000 tons of zinc and 300 tons of cadmium.

On February 6-8, 1979, the Second International Cadmium Conference was held in Cannes, France. The conference was jointly sponsored by the Cadmium Association of London, The Cadmium Council, and the International Lead-Zinc Research Organization, Inc., of New York, and dealt primarily with the technical, economic, and occupational health and environmental aspects of cadmium.

On August 30, 1979, the Government of Sweden ratified a decision by the Swedish Product Control Board to impose a partial ban on the importation and use of cadmium. Exemptions from the ban, which was due to become effective in 1980, would be extended to industries that cannot replace cadmium with other materials or that can control the amount of cadmium released into the environment.

Table 9.—Cadmium: World smelter production,[1] by country

(Metric tons)

Continent and country	1976	1977	1978[p]	1979[e]
North America:				
Canada (refined)	1,314	1,185	964	1,480
United States[2]	2,047	1,999	[3]1,653	[3]1,715
Latin America:				
Mexico (refined)	710	908	897	990
Peru	174	182	[e]190	220
Europe:				
Austria	29	26	33	35
Belgium	1,196	1,434	1,139	1,420
Bulgaria[e]	220	200	210	210
Finland	428	527	611	600
France	532	790	694	790
German Democratic Republic[e]	20	20	20	20
Germany, Federal Republic of	1,275	1,336	1,182	1,170
Italy	[r]436	449	383	460
Netherlands[e]	[r]397	302	402	400
Norway	80	97	120	110
Poland	[e] [r]750	754	761	766
Romania[e]	100	90	90	90
Spain	246	303	253	230
U.S.S.R.[e]	2,700	2,750	2,800	2,850
United Kingdom	190	295	291	410
Yugoslavia	[e]180	189	185	200
Africa:				
South-West Africa, Territory of	[r]83	80	70	70
Zaire	266	246	186	240
Zambia	7	4	[e]4	4
Asia:				
China, mainland[e]	[r]100	[r]100	120	120
India	34	44	113	180
Japan	2,500	2,844	2,530	2,590
Korea, North[e]	[r]110	[r]110	110	110
Oceania: Australia (refined)	649	[r]671	754	800
Total	16,773	17,935	16,765	18,280

[e] Estimate. [p] Preliminary. [r] Revised.

[1] This table gives unwrought metal production from ores, concentrates, flue dusts, and other materials of both domestic and imported origin. Sources generally do not indicate if secondary metal (recovered from scrap) is included or not; where known, this has been indicated by footnote. Data derived in part from World Metal Statistics (published by World Bureau of Metal Statistics, London) and from Metal Statistics (published by Metallgesellschaft Aktiengesellschaft, Frankfurt am Main). Cadmium is found in ores, concentrates, and/or flue dusts in several other countries, but these materials are exported for treatment elsewhere to recover cadmium metal; therefore, such output is not recorded in this table to avoid double counting.

[2] Includes secondary.

[3] Final figure.

TECHNOLOGY

A 9-volt, rechargeable, nickel-cadmium battery was developed utilizing sealed cylindrical cell technology. Potential applications were in calculators and radios. Reported advantages include quick recharging, long life, high-rate discharge, and no maintenance.[9] Cadmium is an essential ingredient in electrical contacts that must resist high temperatures, wear, and seizing. Recent patents on electrical contacts employing alloys of cadmium include contacts resistant to wear and seizing which employ a sintered silver- cadmium alloy, and high-current electrical contacts produced by liquid-phase sintering of cadmium-tungsten-silver alloys.[10]

Cadmium sulfide, when quenched under a pressure of nearly 600,000 pounds per square inch, is partially transformed into a glassy, metallic, reversibly magnetic phase that seems to function as a magnetically controllable superconductor at room temperature. This discovery could lead to the development of ultrafast solid state computer switches and a broad range of other electromagnetic devices.[11]

A new analytical reagent was developed that is both sensitive and highly selective for cadmium and does not react with zinc. By the addition of appropriate masking agents, the reaction is made specific for cadmium.[12] A method for determining cadmium in feces was developed and used to estimate the average daily cadmium intake in different age groups in Sweden. It was observed that smokers had a higher daily fecal cadmium content than nonsmokers. Age-related changes in daily fecal cadmium were also observed.[13]

Research directed toward reducing and

controlling industrial emissions of cadmium to the environment continued to be an important area of investigation. A new method for recovering metals, including cadmium, from dilute solutions was developed in England. The process, which uses a fluidized bed of glass beads 0.0005 millimeter in diameter in combination with screenlike, expanded mesh electrodes, can reportedly recover metals from dilute solutions such as electroplating rinse-tank fluids, where the typical concentrations are 100 to 200 parts per million.[14] A safe cadmium emission threshold limit during typical brazing operations and ways of preventing toxic fumes of cadmium oxide from reaching workers were developed, and recommendations for safe practice were presented. The safe threshold limit reported for cadmium oxide is 0.05 milligram per cubic meter of air measured as cadmium. A booth developed for safe brazing operations was described.[15]

The Bureau of Mines conducted research aimed at developing economical techniques for greater recovery of cadmium and other substances from both liquid and solid industrial process discharge streams. The Bureau developed a pyrometallurgical method for recovering metallic cadmium and nickel-iron residue low in cadmium from scrapped nickel-cadmium batteries.[16]

Developments in cadmium technology are abstracted in Cadmium Abstracts, a bimonthly publication available through the Cadmium Association, 34 Berkley Square, London W1X 6AJ, England.

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[1] Physical scientist, Section of Nonferrous Metals.

[2] Federal Register. Solid Waste Disposal Facilities. V. 43, No. 25, Feb. 6, 1978, pp. 4942-4955.

[3] Federal Register. Protection of Environment. Part 440, Ore Mining and Dressing Point Source Category. V. 43, No. 133, July 11, 1978, pp. 29771-29781.

[4] Federal Register. Toxic Substances Control. V. 43, No. 208, Oct. 26, 1978, pp. 50140-50147.

[5] Federal Register. Lead and Cadmium in Decorated Glass Tumblers. V. 43, No. 242, Dec. 15, 1978, p. 58633.

[6] Federal Register. Effluent Guidelines and Standards; Electroplating Point Source Category; Pretreatment Standards for Existing Sources. V. 44, No. 175, Sept. 7, 1979, pp. 52590-52629.

[7] Federal Register. Criteria for Classification of Solid Waste Disposal Facilities and Practices. V. 44, No. 179, Sept. 13, 1979, pp. 53438-53468.

[8] Quantities in metric tons unless otherwise noted.

[9] Nickel Topics. GE Comes Out With 9-Volt Rechargeable Battery. V. 31, No. 1, 1978, pp. 14-15.

[10] Kim, H. J., F. J. Reid, and F. J. Scimeca (assigned to GTE Laboratories, Inc.) Refractory Metal Silver-Cadmium Alloys. U.S. Pat. 4,088,480, May 9, 1978.

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[13] Kjellstrom, T., K. Borg, and B. Lind. Cadmium in Feces as an Estimator of Daily Cadmium Intake in Sweden. Environ. Res., v. 15, No. 2, 1978, pp. 242-251.

[14] Chemical Engineering. V. 85, No. 28, Dec. 18, 1978, p. 44.

[15] British Association for Brazing and Soldering. Recommendations for the Safe Use of Cadmium-Containing Filler Metals for Brazing. July 1978, 11 pp.; available from BNF Metals Technology Center, Grove Laboratories, Denchworth Road, Wantage, Oxfordshire, OX129BJ, England.

[16] Wilson, D. A. Recovery of Cadmium From Ni-Cd Scrap Batteries. Proc. 6th Miner. Waste Utilization Symp., U.S. Bureau of Mines and IIT Research Institute, Chicago, Ill., May 2-3, 1978, pp. 420-423.

Calcium and Calcium Compounds

By J. W. Pressler[1]

Calcium metal was manufactured by one company in Connecticut. Calcium chloride was produced by two companies in California and two companies in Michigan. Synthetic calcium chloride was manufactured by one company in New York and two companies in Washington.

DOMESTIC PRODUCTION

Pfizer Inc. produced calcium metal at Canaan, Conn., by an aluminothermic process in which high-purity quicklime and aluminum powder are briquetted and heated in vacuum retorts. At 1,170° C, calcium vaporizes and is collected at the other end of the retort, which has a water-cooled condenser.

National Chloride Co. of America and Leslie Salt Co. produced calcium chloride from wells in San Bernardino County, Calif. Average output increased 20% in 1978, but decreased 13% in 1979, compared with that of the previous year. The Dow Chemical Co., Velsicol Chemical Corp., and Wilkinson Chemical Corp. recovered calcium chloride from brine in Gratiot, Lapeer, Mason, and Midland Counties, Mich.; however, Velsicol's plant was shut down in 1978. Average output in Michigan increased 9% in 1978, but decreased 5% in 1979, compared with that of the previous year. Total production of natural calcium chloride in 1978 was 773,000 tons, an increase of 9% compared with 1977 production; total production in 1979 was 719,700 tons, a decrease of 7% compared with that of 1978.

Allied Chemical Corp. recovered synthetic calcium chloride as a byproduct of soda ash at Syracuse, N.Y.; Reichold Chemicals, Inc., recovered synthetic calcium chloride as a byproduct of pentachlorophenol manufacture at Tacoma, Wash.; and Hooker Chemicals & Plastics Corp. manufactured calcium chloride at Tacoma using limestone and hydrochloric acid. Total output of synthetic calcium chloride in 1978 was 258,000 tons, a slight increase compared with the 1977 level; in 1979, output was 251,000 tons, a decrease of 3% compared with the 1978 level.

Table 1.—Production of calcium chloride (75% $CaCl_2$ equivalent) in the United States

Year	Natural		Synthetic		Total	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1975	594,400	$29,047	233,869	$15,137	828,269	[1]$44,183
1976	648,979	32,889	248,272	14,381	897,251	47,270
1977	710,385	45,048	257,231	17,683	967,616	62,731
1978	773,138	53,868	257,763	21,172	1,030,901	75,040
1979	719,709	51,884	261,052	22,566	980,761	74,450

[1]Data do not add to total shown because of independent rounding.

CONSUMPTION AND USES

Calcium metal was used as a reducing agent to recover refractory metals such as tantalum, uranium, and zirconium from their oxides; to form alloys with metals such as aluminum, lead, and silicon; as a desulfurizer and deoxidizer in steel refining; in the manufacture of calcium hydride used in the production of chromium, titanium, and zirconium in the Hydromet process; and as an aid in removing bismuth from lead in refining. Some minor, but interesting, uses were in the preparation of vitamin B, and as a cathode coating in some types of photo tubes.

A high growth rate was forecast for the use of calcium in the battery sector, particularly in the maintenance-free (MF) lead-calcium (0.1% Ca) automotive storage battery. As with nickel-cadmium batteries, the lead batteries were completely sealed, and replacement of the electrolyte is not necessary. They were sold particularly on their merit of being of long life. Demand in the United States continued strong throughout the year.

The MF battery continued to consume the major portion of calcium metal supply, with Detroit equipping all passenger cars by yearend 1979.

In addition to its use in the refining of steel, calcium was used as an additive to high-tensile steels, such as those used in oil pipelines. Research has pointed to possibilities of using calcium additives in other high-quality steels.

The principal use of calcium chloride was to melt snow and ice from roads, streets, bridges, and pavements. Calcium chloride is more effective at lower temperatures than rock salt and is mainly used in the Northern and Eastern States. Because of its considerably higher price, it is used in conjunction with rock salt for maximum effectiveness and economy. It was also used to stabilize the surface of roads and driveways for dust control and as a set-accelerator for concrete.

Velsicol Chemical Corp., a subsidiary of Northwest Industries, was forced to close its St. Louis, Mich., chemical plant in September 1978 because of environmental pollution of polybrominated biphenyls. At least 60,000 tons per year of 78%-equivalent $CaCl_2$ was lost to the marketplace, and disrupted a market that had price increases totaling over 14% for that year.

Sales of calcium bromide as a packer and completion solids-free fluid for oil and gas wells doubled in the 1978-79 period. The Dow Chemical Co. expanded its Midland, Mich., plant capacity in 1979 to 120 million pounds annually.[2] A new facility at its Magnolia, Ark., plant is also being added, with an annual capacity of 120 million pounds of calcium bromide, to be completed in 1981.[3]

Great Lakes Chemical Corp. of West Lafayette, Ind., has also increased its calcium bromide production, and has penetrated the market appreciably.[4]

PRICES AND SPECIFICATIONS

The price of calcium metal crowns increased from $1.64 per pound to $1.80 per pound on October 16, 1978, and to $1.89 per pound on January 1, 1979, maintaining that level throughout 1979. The price of calcium-silicon alloy increased from 51 cents per pound to 54 cents per pound on April 1, 1978; to 57 cents per pound on October 1, 1978; and to 71 cents per pound on October 1, 1979. Yearend published prices and specifications for 1978 and 1979 were as follows:

	Value per pound	
	1978	1979
Calcium metal, 1-ton lots, 50-pound full crowns, 10 by 18 inches, Ca + Mg 99.5%, Mg 0.7%	$1.80	$1.89
Calcium-silicon alloy, 82% calcium, carload lots, f.o.b. shipping point	.57	.71

Sources: Metals Week. V. 50, No. 1, Jan. 1, 1979, p. 5; No. 53, Dec. 31, 1979, p. 7.

Calcium metal is usually sold in the form of crowns, broken pieces, or billets, shipped in 55-gallon metal containers with a maximum of 300 pounds, and gasketed to provide an airtight condition, with argon atmosphere provided if desired. The value for imported calcium metal in 1978 ranged from $0.68 to $1.82 per pound, and averaged $1.66 per pound for the year. In 1979, comparable values ranged from $0.95 to $2.07 per pound, and averaged $1.41 per pound for the year. This did not include the assessed tariff, which was 7.5% ad valorem for Most Favored Nation status and 25% ad valorem for Non-Most Favored Nation status.

Calcium chloride is usually sold either as solid flake or pellet averaging about 75% $CaCl_2$, or as a concentrated liquid averaging about 40% $CaCl_2$. The price of calcium chloride increased 40% for 1978 and 1979, although published prices did not indicate this. Yearend published prices and specifications for 1978 and 1979 were identical, as follows:

	Value per ton[1]	
	1978	1979
Calcium chloride, regular grade, 77% to 80%, flake, bulk, carload, works	$67-$70	$67-$70
Calcium chloride, liquid, 40% to 45%, tankcar or tanktruck, works	28.25	28.25

[1] Differences between high and low price are accounted for by differences in quantity, quality, and location.

Sources: Chemical Marketing Reporter. V. 215, No. 1, Jan. 1, 1979, p. 47; v. 216, No. 27, Dec. 31, 1979, p. 31.

As reported by producers on an f.o.b. warehouse basis, with conversions of all products to a 75% $CaCl_2$ basis, the average value in 1978 for natural calcium chloride was $69.67 per ton; the average value for synthetic calcium chloride was $82.14 per ton. Combining natural and synthetic products, the average value of solid 75% $CaCl_2$ for the year was $79.42 per ton, and the average value of liquid 40% $CaCl_2$ was $31.91 per ton. Likewise in 1979, the average value of solid 75% $CaCl_2$ for the year was $89.06, and the average value of liquid 40% $CaCl_2$ was $25.89 per ton.

FOREIGN TRADE

The following section contains foreign trade statistics for 1978 and 1979. Those for 1979 are in parentheses.

Exports of calcium phosphates were 129,532 (559,963) tons valued at $19,452,000 ($24,114,000), compared with 53,309 tons valued at $9,550,000 in 1977; leading destinations were Canada, the United Kingdom, Mexico, and Venezuela (Canada, Mexico, the United Kingdom, Venezuela, and Thailand). Exports of calcium chloride, mainly to Canada and Mexico, were 45,099 (30,307) tons valued at $4,539,000 ($5,722,600), compared with 39,552 tons valued at $3,383,000 in 1977. Exports of other calcium compounds, including precipitated calcium carbonate, mainly to Canada, the Netherlands, and Mexico (Mexico, Canada, the Netherlands, Saudi Arabia, and the Republic of the Philippines), totaled 22,519 (20,417) tons valued at $10,139,000 ($11,874,000), compared with 14,887 tons valued at $4,053,000 in 1977.

Total imports of calcium and calcium compounds were 297,400 (323,600) tons valued at $29.3 ($36.2) million. Imports of calcium metal from Canada, the U.S.S.R., and the United Kingdom (the U.S.S.R., Canada, and Japan) were 262 (359) tons valued at $825,000 ($1.0 million). Imports of calcium chloride, mainly from Canada, were 42,523 (58,091) tons valued at $2.1 ($3.0) million. Imports of other calcium compounds, mainly from Norway, Turkey, Canada, the United Kingdom, and France (Norway, Turkey, France, the Netherlands, Canada, and the United Kingdom) totaled 254,600 (265,200) tons, valued at $26.4 ($32.1) million.

Imports of other calcium compounds included 99,513 (123,061) tons of calcium nitrate, mainly from Norway; 94,053 (81,228) tons of calcium borate, mainly from Turkey; 33,286 (34,087) tons of chalk whiting, mainly from France; 10,973 (8,969) tons of precipitated calcium carbonate, mainly from the United Kingdom, Japan, and France (the United Kingdom, France, and Japan); 6,611 (7,217) tons of calcium carbide from Canada; 2,017 (1,946) tons of calcium cyanamide, mainly from Canada; 1,838 (3,599) tons of calcium hypochlorite, mainly from Japan and India; and 6,237 (5,062) tons of other compounds, mainly from the United Kingdom, the Federal Republic of Germany, Mexico, and Canada (the United Kingdom, Canada, and Japan).

Table 2.—U.S. imports for consumption of calcium and calcium chloride, by year

Year	Calcium		Calcium chloride	
	Quantity (pounds)	Value[1]	Quantity (short tons)	Value[1]
1974	109,252	$120,883	3,599	$155,727
1975	70,128	77,684	12,021	597,758
1976	461,965	475,119	16,046	480,259
1977	458,319	705,634	19,708	1,002,386
1978	523,835	825,008	42,523	2,101,794
1979	717,726	1,015,183	58,091	3,018,443

[1] U.S. Customs import value, generally representing value in foreign country, and, therefore, excluding U.S. import duties, freight, insurance, and other charges incurred in shipping merchandise to the United States.

Table 3.—U.S. imports for consumption of calcium chloride, by country

(Short tons)

Country	1978		1979	
	Quantity	Value[1]	Quantity	Value[1]
Canada	42,198	$2,010,425	57,993	$2,920,938
Denmark	1	450	--	--
France	--	--	3	4,405
Germany, Federal Republic of	82	46,773	91	86,829
Ireland	(2)	643	(2)	984
Japan	220	37,888	(2)	450
Netherlands	22	4,360	--	--
Sweden	(2)	686	4	2,926
Switzerland	--	--	(2)	305
United Kingdom	(2)	569	(2)	1,656
Total	42,523	2,101,794	58,091	3,018,443

[1] U.S. Customs import value. See detailed explanation in footnote 1 of table 2.
[2] Less than 1/2 unit.

WORLD REVIEW

The market economy world annual production of calcium metal is estimated to be between 1,400 and 1,600 short tons. Major increases in Soviet exports to the United States in 1979 indicated a magnitude estimate of its production to be 1 million pounds annually.

Canada.—Chromasco Corp. Ltd. produced calcium metal at its Haley smelter near Renfrew, Ontario. Canada continued to lead all other countries in the production of calcium metal in 1978, producing about 1,267,000 pounds. Most of it was exported to the United States (34%), with lesser amounts to the Republic of South Africa and Mexico (6% each). About 439,000 pounds valued at $770,000 was exported to the United States. In 1979, Canada produced about 1,052,000 pounds of calcium metal valued at $2,008,000. U.S. imports from Canada for the year were 296,000 pounds, valued at $613,000, a decrease of 33% compared with the 1978 level.

Canada was the leading source of U.S. imports of calcium chloride. U.S. imports more than doubled, from 19,700 tons in 1977 to 42,198 tons in 1978, and increased 37% in 1979 to 57,993 tons.

U.S. exports of calcium chloride to Canada increased from 28,975 tons in 1978 to 30,307 tons in 1979.

France.—Planet Wattohm S.A., a subsidiary of Compagnie de Mokta, produced calcium metal by the Pidgeon process. No metal was exported to the United States in 1978 and 1979. Expansion of MF storage battery production to Europe is underway, with General Motors Corp. building a plant in France. A major portion of the batteries produced will be exported to other European countries for automotive use.

U.S.S.R.—Substantial quantities of calcium metal was produced in the U.S.S.R. Fifty-five tons of Soviet calcium metal valued at $75,000 was exported to the United States in 1978, but this increased dramatically in 1979 to 211 tons valued at $402,000, and represented 59% of all U.S. calcium metal imports for the year.

TECHNOLOGY

Increased demand for calcium bromide high-density, solids-free liquids in the completion of oil and gas wells was experienced in 1978 and 1979. Refinements of technology have emphasized better production techniques in unconsolidated formations, diversification of specific gravity formulations from 9.1 pounds per gallon (principally $CaCl_2$) to as high as 19.1 pounds per gallon (higher percentages of $CaBr_2$ and $ZnBr_2$), and recycling of spent liquid for reprocessing and more efficient utilization. Greater demand was experienced in land-based wells because of easier control and utilization.[5]

A heat-storage battery has been developed by Pipe Systems Inc. (St. Louis, Mo.) and The Dow Chemical Corp. (Midland, Mich.), consisting of 30 pounds of calcium chloride hexahydrate phase-change material encapsulated in 6-foot-long by 3-1/2-inch-diameter polyethylene cylinders. Heat is stored as the latent heat of fusion (82 Btu per pound) when the salt melts at 81° F., and is released when it crystallizes. According to Pipe Systems, 100 rods at $30 each (under warranty for 10 years and with an expected lifetime of 20 to 40 years) store ample heat for an average house.[6]

W. R. Grace & Co., New York, N.Y., has developed a new inorganic compound that can be added to concrete to prevent corrosion in bridges. The product, called a Darex Corrosion Inhibitor, is a compound of calcium nitrite and water that is added to the concrete at the ready-mix plant in proportion of 2% to 4% by weight of the cement. The compound is said to prevent corrosion by reacting chemically with the steel that the concrete contacts. According to Grace, the compound was developed after 15 years of research.[7]

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[1] Physical scientist, Section of Nonmetallic Minerals.

[2] Chemical & Engineering News. V. 57, No. 4, Jan. 22, 1979, p. 15.

[3] Chemical Marketing Reporter. V. 215, No. 11, Mar. 12, 1979, p. 3.

[4] Great Lakes Chemical Corp. Annual report, 1978, p. 10.

[5] Dowell Division of The Dow Chemical Co. (Houston, Tex.). Private communication, Apr. 1, 1980.

[6] Chemical & Engineering News. V. 57, No. 19, May 7, 1979, p. 15.

[7] Chemical Week. V. 125, No. 1, July 4, 1979, p. 39.

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Cement

By James T. Dikeou[1]

Portland cement shipments from plants in the United States and Puerto Rico, including cement imported and distributed by domestic producers, totaled 83.8 million tons in 1978 and 83.4 million in 1979. Shipments in 1979 were 7% higher than shipments in 1977 but 4% less than the 1973 record high cement shipments of 86.6 million tons. Mill value of these shipments increased to $3.4 and $3.9 billion, respectively, for 1978 and 1979, 21% and 39% higher, respectively, than that of 1977. This reflects an increase in the unit value of $4.35 and $9.88 per ton respectively, for 1978 and 1979, or 12% and 27%, respectively, compared with that of 1977.

Demand for cement during the 2-year period was strong in most end use sectors. Housing starts in 1978 remained high, at about 2 million units, dropping to 1.7 million units in 1979. In addition, nonresidential building exceeded expectations. Total cement sales in constant dollars rose 13% in 1978 and 17% in 1979 compared with 1977 sales. Much of the increased cement demand was west of the Appalachians. Cement production capacities in 1978 were not adequate to meet demand in many parts of the West and severe shortages were chronic throughout the year particularly in Washington, Oregon, California, and Arizona. Although production of cement for 1979 was about the same level as in 1978, the shortages of the previous year did not occur. During this 2-year reporting period, production was affected by isolated strikes, conversion to coal burning, installation of pollution control facilities to meet environmental regulations, operating difficulties, shortages of special railcars, and the inability to raise capital for expansion of this capital-intensive industry.

Over the previous 20 years, cement consumption had risen at an average annual rate of about 2.3%. This is a slightly higher rate than that of construction as measured in constant dollars. Contributors to the higher consumption of portland cement include concrete slip form pavers for highway construction; the use of cement for slope protection in reservoirs; shotcreting for mine shaft-lining systems; concrete overlays on highways and airport runways as a means of rehabilitation, mainly since 1973; increased use of concrete rail ties; special admixtures permitting the manufacture of higher strength concrete; and wider use of prestressed and precast structures for industrial plants, box girders, bridge decks, and rapid transit systems.

New cement plants being built or modernized are designed to minimize labor through the use of automated equipment. This factor has contributed to labor productivity gains in the cement industry where tons-per-employee-hour have risen from 0.9 in 1960 to 2.3 in 1979. During this period, portland cement manufacturing capacity increased from 81 million tons to 106 million tons in 1979. In contrast the number employed has dropped from 35,000 to 24,000.

Several new capacities came onstream including one new plant, four modernizations, and expansions and the startup of a plant that was closed in 1976. Estimates of the capacity added is about 2 million tons. However, in general, capacity increases have been impeded by government legislation and regulation on both the Federal and State levels.

Energy continued to be a major concern in the cement industry. In keeping with a trend set in motion by the fuel crises of 1974, a number of kilns were converted to coal as the primary fuel. In addition, several companies were experimenting with the burning of industrial wastes, waste oil, and a variety of combustible materials other than coal, oil, or natural gas. Another recent movement has been the acquisition of coal deposits and coal mines by cement producers. At least five companies announced plans for the development of coal reserves and mining facilities.

Civil antitrust suits originally filed in 1976 by the attorney's general of California, Arizona, and Colorado against the Portland Cement Association and a number of cement producers alleging a conspiracy to fix, maintain, and stabilize cement prices remained very much an issue. Other States joining the original three include Alabama, Florida, Kansas, Louisiana, Minnesota, Missouri, Montana, Nebraska, New Mexico, Oregon, Texas, and Utah. The actions were scheduled to be heard in the District Court for the United States for the District of Arizona in September 1980.

Table 1.—Salient cement statistics

(Thousand short tons and thousand dollars)

	1975	1976	1977	1978	1979
United States:[1]					
Production[2]	68,139	72,950	78,647	83,986	84,491
Shipments from mills[2 3]	69,102	73,668	80,247	86,557	85,747
Value[2 3 4]	$2,159,160	$2,510,100	$2,932,403	$3,543,996	$3,991,580
Average value per ton[2 3 4]	$31.25	$34.07	$36.54	$40.94	$46.55
Stocks, Dec. 31 at mills[2]	6,930	7,154	6,041	5,320	6,600
Exports	417	343	236	55	149
Imports for consumption	3,637	3,074	3,989	6,577	9,393
Consumption, apparent[5 6]	70,062	74,136	81,537	87,619	87,799
World: Production	773,989	[r]822,418	[r]872,894	938,095	[p]957,791

[p]Preliminary. [r]Revised.

[1] Excludes Puerto Rico.

[2] Portland and masonry cement only.

[3] Includes imported cement shipped by domestic producers.

[4] Value received, f.o.b. mill, excluding cost of containers.

[5] Quantity shipped, plus imports, minus exports.

[6] Adjusted to eliminate duplication of imported clinker and cement shipped by domestic cement manufacturers.

DOMESTIC PRODUCTION

During 1978-79, 1 State agency and 57 companies operated 162 plants in 39 States. An additional two companies operated two plants in Puerto Rico, manufacturing one or more kinds of hydraulic cement.

Some of the tables show statistical data arranged by State or by groups of States that form cement districts. A cement district may represent a group of States or a portion of a State. The States of California, New York, and Pennsylvania have, on some tables, been divided to provide additional marketing information. Divisions for these States are as follows:

California, Northern.—Points north and west of the northern borders of San Luis Obispo and Kern Counties and the western borders of Inyo and Mono Counties.

California, Southern.—All other counties in California.

New York, Western.—All counties west of a dividing line following the eastern boundaries of St. Lawrence, Lewis, Oneida, Madison, Chenango, and Broome Counties.

New York, Eastern.—All counties east of the above dividing line.

New York, Metropolitan.—The five counties of New York City (Bronx, Kings, New York, Queens, and Richmond) plus Westchester, Rockland, Suffolk, and Nassau Counties.

Pennsylvania, Eastern.—All counties east of the eastern boundaries of Potter, Clinton, Centre, Huntingdon, and Franklin Counties.

Pennsylvania, Western.—All other counties in Pennsylvania.

PORTLAND CEMENT

As appropriate throughout the remainder of this report, where different values exist for 1978 and 1979, the 1978 values are shown first, with the 1979 values immediately following in parentheses.

Manufacturers in the United States and Puerto Rico produced 75.5 (76.1) million tons of clinker and imported 3.0 (4.2) million tons of clinker to grind 81.4 (82.1) million tons of portland cement. Stocks at mills decreased by 700,000 tons during 1978, but increased 1.2 million tons during 1979.

Production Capacity.—During 1978-79, multiplant operations were run by 24 companies. Company size, as indicated by percentages of the national total clinker production capacity of individual companies, ranged from 7.2% (6.8%) to 0.25% (0.09%).

The 5 largest producers provided 28% (28%) of the total production capacity; the 10 largest provided for a combined 48.5% (46.4%). At the end of 1979, the 10 largest companies, in terms of clinker production capacity, were (1) Ideal Basic Industries, Inc.; (2) Lone Star Industries, Inc.; (3) Martin Marietta Corp.; (4) General Portland, Inc.; (5) Kaiser Cement Corp.; (6) Amcord, Inc.; (7) National Gypsum Co.; (8) Marquette Cement Co.; (9) Medusa Corp.; and (10) Southwestern Portland Cement Co.

At the end of 1979, 377 kilns located at 157 plants were being operated by 50 companies and 1 State agency in the United States and Puerto Rico. Estimated annual clinker production capacity at yearend was 89.1 (89.7) million tons. An average of 54 (57) days downtime was reported for kiln maintenance and replacing refractory brick. Annual clinker production of the industry was 75.5 (76.1) million tons. The industry operated at 85% (85%) of its apparent capacity, compared with 82% in 1977. Average annual clinker capacity of U.S. kilns was 234,000 (237,900) tons; average plant capacity was 567,000 (571,000) tons and average company capacity was 1,747,000 (1,759,000) tons. Of the 157 clinker-producing plants, 6 produced white cement. In addition, 12 plants operated grinding mills using only imported or purchased clinker, or interplant transfers of clinker. Of these 12, 11 had for some years operated in this manner; the other operated from mid-1978. This latter plant was normally a clinker producer but had closed its kilns in 1976 and restarted them in 1979. Of the 11 grinding plants in 1979, 6 produced portland cement only, 1 ground clinker for both masonry and portland cement, and 4 produced only masonry cement. Based on the fineness necessary to grind Types I and II cements and making allowance for downtime required for maintenance, the cement industry in the United States and Puerto Rico had an estimated annual grinding capacity of 105 (106.5) million tons of cement.

During 1978-79, clinker was produced by wet-process kilns at 89 (88) plants and by dry-process kilns at 61 (61) plants; 7 (8) additional plants operated both wet and dry kilns. All new plants that came onstream in 1978-79 and those currently under construction are dry-process, preheater equipped, single-kiln systems with capacities in excess of 500,000 tons of clinker. Newer plants, expected onstream in the early 80's, are planned to be equipped with flash calciners. The trend towards increasingly large and high-capacity cement kilns has led, in Japan and Europe, to the development of precalcining processes in which the input of heat is divided between two firing systems. The secondary firing system, installed between the cyclone preheater and rotary kiln, is fed up to 60% of the required fuel. The kiln feed material is up to about 90% calcined before entering the kiln. Advantages of precalcination include reduced consumption of refractory lining material, high kiln utilization, lower nitric oxide emissions, and the use of lower grade fuels. However, for equal throughout performance, the heat consumption is slightly higher than that of the conventional process with cyclone preheaters. During 1978, 5 new suspension preheaters were put into operation, bringing the yearend totals to 40 suspension and 14 grate preheaters. At the end of 1979, 38 suspension and 11 grate preheaters were reported to be in operation.

Capacity Added in 1978.—Centex Cement Corp. in mid-1978 opened a new plant at a new site, Buda, Tex. (near Austin). Plant capacity is rated at 500,000 tons and construction cost was $32 million.

Coplay Cement Manufacturing Co. in March 1978 put onstream its new plant at its existing Nazareth, Pa. site. Plant capacity is rated at 1.1 million tons and was constructed at a cost of $50 million. There is no net capacity increase due to shutdown of old plants. Coplay is a wholly owned U.S. subsidiary of Societe des Ciments Francais.

Lehigh Portland Cement Co. in October 1978 completed the modernization and expansion program it started in 1976 at its Mason City, Iowa plant. Net capacity change adds about 150,000 tons, bringing total plant capacity to 750,000 tons. Total cost was about $25 million. Lehigh is a wholly owned subsidiary of the Portland-Zementwerke, Heidelberg A.G.

Lone Star Lafarge Inc. completed construction of a new plant to manufacture "SECAR" brand high-purity calcium aluminate cement, a premium-priced cement with applications in refractories, chemical processes, and other special industrial uses. The new plant is located at Chesapeake, Va., an existing site, and was designed and engineered by Lone Star Lafarge Consultants Ltd., Canada. Capacity change was not announced.

South Dakota Cement Co. in early 1978 completed its expansion and modernization program at its existing facility at Rapid

City, S. Dak. New capacity added was about 500,000 tons at a cost of $27.8 million. South Dakota Cement Co. is owned by the State of South Dakota.

Southwestern Portland Cement Co. in mid-1978 finished modernizing its Odessa, Tex. plant. New capacity added was about 260,000 tons.

Plants Reopened in 1978.—Two old plants were reopened under new management. The Independent Cement Corp. reactivated the former Colonial Sand & Stone Co., Inc. plant, at Kingston, N.Y. It had a lease with option to buy and planned to improve this operation further. Reactivated capacity was rated at 750,000 tons.

SME Cement, Inc., a newly organized cement producer, restarted the Diamond-Flintkote Co. plant at Middlebranch, Ohio. The plant had been forced to shut down due to environmental control factors begining in late 1975 with final shutdown in mid-1976. SME Cement, Inc., bought the plant in 1977 and began grinding purchased clinker in mid-1978. Clinker production began again in 1979 in two of the four kilns. Both are dry process, coal fired. New capacity onstream is approximately 275,000 tons.

Capacity Changes in 1979.—Ideal Cement Co. completed construction early in 1979 of their new preheater-precalciner kiln at Knoxville, Tenn. Cost of construction was $50 million. The new dry-process, 580,000-ton-capacity kiln replaced old wet-process kilns, and increased the total capacity at this plant by 110,000 tons.

OKC Corp.'s $22 million expansion of their Pryor, Okla., plant was essentially completed by the end of 1979. Plant capacity was increased from 450,000 tons to 750,000 tons through the addition of a third kiln and new primary crusher, storage, and blending facilities. New pollution control equipment was also installed.

In late December of 1979, Kaiser Cement Corp. completed modernization of its San Antonio, Tex. plant. The project, which cost $16.5 million, consisted of replacing three old wet-process kilns with a new dry process kiln with preheater and precalciner. Capacity remained at 490,000 tons of finished cement.

Oregon Portland Cement Co. in 1979 opened its new plant at Durkee, Oreg. The 500,000-ton-capacity, dry-process preheater plant, constructed at a cost of $46 million, replaced the company's old 200,000-ton-capacity plant.

Texas Industries, Inc., completed construction of its new cement plant at Hunter, Tex. The 550,000-ton-per-year-capacity, dry-process plant includes a preheater-precalciner system, and was constructed at a cost of $50 million.

Portland Cement Co. of Utah added a new 11- by 300-foot wet-process kiln, replacing two small kilns, to increase its plant capacity from 260,000 to 420,000 tons per year.

Capacity Changes Scheduled for Completion During the Period 1980-81.—Several major clinker capacity increases are expected as summarized in the following text table.

Company	Location	Process Preheater	Cost (millions)	Capacity (thousand tons) From	To	Difference
New:						
General Portland, Inc	Balcones, Tex	D, SP, PC	$85	--	925	925
Expansions:						
Ideal Basic Industries, Inc	Boettcher, Colo	D, GP	34	325	460	135
Martin Marietta Corp	Lyons, Colo	D, SP, PC	7	434	451	17
Medusa Corp	Charlevoix, Mich	D, SP, PC	50	750	1,370	620
Total 1980						1,697
New:						
Ideal Basic Industries, Inc	Thedore, Ala	D, RSP, PC	175	--	1,500	1,500
Expansions:						
California Portland Cement Co	Mojave, Calif	D, SP, PC	100	1,100	2,100	1,000
The Flintkote Co	Redding, Calif	D, SP, PC	42	290	600	310
Kaiser Cement Corp	Permanente Calif	D, RSP	97	1,600	1,600	0
Lone Star Industries, Inc	Santa Cruz, Calif	D, SP	65	395	750	355
Marquette Cement Co	Cape Girardeau, Mo	D, RSP	80	275	1,000	725
Martin Marietta Corp	Davenport, Iowa	D, SP, PC	80	500	850	350
Total 1981						4,240

D Dry. GP Grate preheater. PC Precalciner. RSP Reinforced suspension preheater. SP Suspension preheater.

Capacity Changes Announced for Completion After 1981.—Three new plants at new sites have been announced but construction dates were not given. Lone Star Industries, Inc., and Texas Crushed Stone Inc., Georgetown, Tex., announced an agreement in principle under which Lone Star will construct a new 1-million-ton-per-year plant at Georgetown, Tex.[2] Lone Star was to purchase the plant site from Texas Crushed Stone adjacent to the latter's existing limestone quarries and Texas Crushed Stone was to supply raw material for the cement plant.

Martin Marietta Cement Corp. began marketing and transportation studies along with a raw material reserve evaluation at a site near Leamington, Utah. Stansbury Mining Corp. signed a multiphase drilling and development contract with Martin Marietta. Drilling was to be in two stages to determine if there were sufficient reserves of limestone and allied raw material to justify a cement plant with a capacity of 500,000 tons per year.[3]

Lone Star Industries, Inc., through its subsidiary Portland Cement Co. of Utah, planned to construct a new 500,000-ton-per-year plant at Grantsville, Utah.

Plant Closing.—In late 1979, G. & W. H. Corson, Inc., stopped manufacturing masonry cement at its Plymouth Meeting, Pa. plant.

Corporate Changes.—Mergers by U.S. companies as well as acquisitions of U.S. cement companies by foreign interests continued. It is estimated that between 10% and 14% of U.S. cement capacity was owned by foreign interests at yearend 1979. Among the corporate changes are the following: Genstar Ltd., a Montreal- based land development conglomerate with roots in Societe Generale de Belgique, obtained 21.5% of the outstanding common stock of the Flintkote Co. in 1978. Through a tender offer to its shareholders made late in 1979 and concluded shortly after yearend, followed by a merger in February 1980, Flintkote became a wholly owned Genstar subsidiary. Total cost of this acquisition was $447 million.

Independent Cement Corp., a subsidiary of St. Lawrence Cement Co., during 1978 entered into a long-term lease with option to purchase, with Colonial Sand & Stone Co., Inc. of New York to operate the closed plant at Kingston, N.Y.

Medusa Corp. was the object of merger attempts by four large corporations during 1978. Medusa became a subsidiary of the Crane Co. and retains its headquarters in Cleveland, Ohio. The consent agreement requires that Crane, prior to about September 1980, divest itself of its Dixon, Ill. cement plant. It also bars the Crane chairman of the board from buying assets or acquiring more than 3% of another cement company.[4]

Amcord, Inc., in 1979 became a wholly owned subsidiary of Gifford-Hill & Co., Inc. Amcord, the nations sixth largest cement producer operated five cement plants in California, Arizona, Michigan, and Pennsylvania.

Santee Portland Cement Co., Holly Hill, S.C., was purchased by Dundee Cement Co. in 1978. The acquistion of the 1.2-million-ton-per-year plant gave Dundee new markets in North Carolina, South Carolina, and parts of Georgia, Florida, and Virginia.

Wyandotte Cement Inc., near Detroit, Mich., was acquired in 1978 by St. Mary's Cement Co., Toronto, Canada, marking the first move outside of Canada by the company. Wyandotte was to grind clinker from St. Mary's Bowmansville, Ontario, Canada plant. Annual grinding capacity was about 350,000 tons.

Table 2.—Portland cement shipped by producers in the United States, by district[1] [2]

(Thousand short tons and thousand dollars)

Type	1978			1979		
	Quantity	Value	Average per ton	Quantity	Value	Average per ton
New York and Maine	4,180	122,006	29.18	4,123	139,593	33.85
Pennsylvania, eastern	4,805	155,921	32.44	4,667	181,019	38.78
Pennsylvania, western	1,945	72,648	37.35	1,841	78,737	42.77
Maryland and West Virginia	2,300	78,016	33.92	2,280	88,570	38.84
Ohio	2,022	75,637	37.40	1,921	87,483	45.54
Michigan	5,917	211,786	35.79	5,683	252,058	44.35
Indiana	2,425	81,757	33.71	2,395	95,549	39.90
Illinois	2,113	80,242	37.98	1,889	79,604	42.14
Tennessee	1,568	60,223	38.40	1,335	57,146	42.80
Kentucky, North Carolina, Virginia	1,871	69,584	37.19	1,775	80,482	45.34
South Carolina	1,940	70,532	36.35	1,831	79,377	43.35
Florida	2,766	111,892	40.45	2,957	126,562	42.80
Georgia	1,435	51,504	35.89	1,335	55,117	41.28
Alabama	2,837	108,972	38.41	2,578	103,187	40.02
Louisiana and Mississippi	1,628	70,100	43.06	1,563	77,937	49.86
Nebraska and Wisconsin	1,125	47,450	42.17	1,218	56,881	46.70
South Dakota	545	21,708	39.82	670	31,273	46.67
Iowa	2,646	107,335	40.56	2,371	109,628	46.23
Missouri	4,733	175,962	37.17	4,430	194,285	43.86
Kansas	2,083	78,717	37.79	2,086	88,619	42.48
Oklahoma and Arkansas	2,791	114,950	41.18	2,702	122,343	45.27
Texas	8,806	401,220	45.56	9,353	475,836	50.87
Wyoming, Montana, Idaho	1,085	49,239	45.38	1,050	55,522	52.87
Colorado, New Mexico, Utah, New Mexico	3,945	185,104	46.92	3,996	206,382	51.64
Washington	1,760	86,671	49.24	1,761	98,650	56.02
Oregon and Nevada	1,005	51,266	51.01	981	54,988	56.05
California, northern	2,866	147,686	51.53	2,894	161,338	55.74
California, southern	6,423	325,800	50.72	6,830	380,477	55.70
Hawaii	441	25,626	58.10	469	29,346	62.57
Puerto Rico	1,442	78,981	54.77	1,406	70,197	49.92
U.S. total or average[3] [4]	81,451	3,318,561	40.74	80,384	3,720,633	46.29
Foreign imports[5]	2,398	94,715	39.49	3,006	135,712	45.14
Total or average	83,849	3,413,276	40.71	83,390	3,856,345	46.24

[1] Includes data for six white cement facilities: Texas (two); Pennsylvania (two); California (one); and Wisconsin (one). Includes data for seven grinding plants as follows: Michigan (two); Wisconsin (two); one each in Florida and New York; and one in Ohio in 1978 and one in Pennsylvania in 1979.

[2] Includes Puerto Rico.

[3] Data may not add to totals shown because of independent rounding.

[4] Includes cement produced from imported clinker.

[5] Cement imported and distributed by domestic producers only.

Table 3.—Portland cement production, capacity, and stocks in the United States, by district[1] [2]

(Thousand short tons)

District	1978					1979				
	Plants active during year	Production[3]	Capacity[4]		Stocks[5] at mills Dec. 31	Plants active during year	Production[3]	Capacity[4]		Stocks[5] at mills Dec. 31
			Finish grinding	Percent utilized				Finish grinding	Percent utilized	
New York and Maine	9	4,081	5,502	74.2	382	9	4,187	5,562	75.3	525
Pennsylvania, eastern	11	4,726	6,563	72.0	397	11	4,872	6,563	74.2	575
Pennsylvania, western	5	2,042	3,087	66.1	189	5	1,946	2,681	72.6	215
Maryland and West Virginia	4	2,281	2,821	80.9	167	4	2,330	2,836	82.1	154
Ohio	6	2,014	2,685	75.0	131	6	2,045	2,735	74.8	211
Michigan	7	5,926	7,384	80.2	380	7	5,776	7,423	77.8	412
Indiana	5	2,567	3,756	68.3	171	5	2,664	3,721	71.6	232
Illinois	4	2,123	2,392	88.8	126	4	1,998	2,796	71.5	228
Tennessee	6	1,518	2,626	57.8	112	6	1,394	2,653	52.5	133
Kentucky, North Carolina, Virginia	3	1,865	2,482	75.1	144	3	1,862	2,482	75.0	186
South Carolina	3	1,959	3,044	64.3	103	3	2.014	3,044	66.2	125
Florida	6	2,990	3,757	79.6	160	6	3,255	3,930	82.8	158
Georgia	3	1,465	1,702	86.1	66	3	1,379	1,702	81.0	80
Alabama	7	2,955	3,839	77.0	162	7	2,682	3,839	69.9	273
Louisiana and Mississippi	4	1,586	1,993	79.6	77	4	1,590	1,993	79.8	114
Nebraska and Wisconsin	5	1,060	1,741	60.9	144	5	1,151	1,741	66.1	148
South Dakota	1	515	720	71.5	43	1	660	1,806	36.5	46
Iowa	5	2,533	3,167	80.0	158	5	2,384	3,287	72.5	218
Missouri	7	4,620	5,166	89.4	316	7	4,368	5,166	84.6	375
Kansas	5	2,063	2,414	85.4	113	5	2,117	2,400	88.2	137
Oklahoma and Arkansas	5	2,774	3,447	80.4	118	5	2,752	3,447	79.8	173
Texas	18	8,624	10,874	79.3	467	18	9,070	10,430	87.0	434
Wyoming, Montana, Idaho	4	1,058	1,199	88.2	73	4	1,049	1,194	87.9	72
Colorado, Arizona, Utah, New Mexico	8	3,899	5,545	70.3	190	8	3,973	5,500	72.2	263
Washington	4	1,880	2,095	89.7	116	4	1,843	2,105	87.6	149
Oregon and Nevada	3	1,006	1,325	75.9	42	3	984	1,325	74.3	62
California, northern	4	2,854	3,316	86.1	153	4	2,941	3,278	89.7	219
California, southern	8	6,461	7,878	82.0	237	8	6,921	8,359	82.8	227
Hawaii	2	438	560	78.2	44	2	451	560	80.5	25
Puerto Rico	2	1,495	1,888	79.2	31	2	1,413	1,888	74.8	37
Total or average	164	81,378	104,968	77.5	5,012	164	82,071	106,446	77.1	6,216

[1] Includes Puerto Rico.

[2] Includes data for six white cement facilities; Texas (two); Pennsylvania (two); California (one); and Wisconsin (one). Includes data for seven grinding plants as follows: Michigan (two); Wisconsin (two), one each in Florida and New York; and one in Ohio in 1978 and one in Pennsylvania in 1979.

[3] Includes cement produced from imported clinker (1978—3,036; 1979—4,171).

[4] Grinding capacity based on fineness necessary to grind Types I and II cement, making allowance for downtime required for maintenance.

[5] Includes imported cement. Source of imports withheld to avoid disclosing company proprietary data.

Table 4.—Clinker capacity and production in the United States, by district, as of December 31[1][2]

District	Active plants: Process used: Wet 1978	Wet 1979	Dry 1978	Dry 1979	Both 1978	Both 1979	Total 1978	Total 1979	Number of kilns 1978	Number of kilns 1979	Daily capacity (thousand short tons) 1978	Daily capacity (thousand short tons) 1979
New York and Maine	6	6	2	2	--	--	8	8	13	13	15.9	15.8
Pennsylvania, eastern	3	3	8	7	--	--	11	10	34	31	20.2	19.1
Pennsylvania, western	3	3	2	2	--	--	5	5	10	10	7.3	7.6
Maryland and West Virginia	2	2	2	2	--	--	4	4	10	10	8.1	8.2
Ohio	2	2	2	3	1	1	5	6	10	12	7.5	8.5
Michigan	4	4	1	1	--	--	5	5	15	15	16.8	16.8
Indiana	2	2	3	3	--	--	5	5	10	10	10.4	10.6
Illinois	--	--	4	4	--	--	4	4	10	10	9.3	10.3
Tennessee	6	5	--	--	--	1	6	6	13	13	5.4	6.6
Kentucky, North Carolina, Virginia	1	1	2	2	--	--	3	3	8	8	6.8	6.9
South Carolina	2	2	1	1	--	--	3	3	7	7	7.3	7.3
Florida	4	4	1	1	--	--	5	5	11	11	11.3	11.3
Georgia	--	--	2	2	1	1	3	3	5	5	4.8	4.8
Alabama	3	3	4	4	--	--	7	7	15	14	11.5	11.7
Louisiana and Mississippi	4	4	--	--	--	--	4	4	8	8	5.6	5.6
Nebraska and Wisconsin	2	2	--	--	1	1	3	3	7	7	3.1	3.1
South Dakota	--	--	--	--	1	1	1	1	4	4	3.3	3.3
Iowa	3	3	2	2	--	--	5	5	13	13	9.5	9.5
Missouri	5	5	2	2	--	--	7	7	12	12	15.3	15.3
Kansas	3	3	2	2	--	--	5	5	15	15	7.3	7.3
Oklahoma and Arkansas	3	3	2	2	--	--	5	5	11	11	8.6	8.7
Texas	12	12	4	4	2	2	18	18	46	46	27.9	28.2
Wyoming, Montana, Idaho	4	4	--	--	--	--	4	4	5	5	3.1	3.1
Colorado, Arizona, Utah, New Mexico	3	3	5	5	--	--	8	8	21	20	13.1	13.3
Washington	3	3	1	1	--	--	4	4	7	7	3.5	3.5
Oregon and Nevada	2	2	1	1	--	--	3	3	7	7	3.3	3.3
California, northern	2	2	2	2	--	--	4	4	13	13	9.5	9.4
California, southern	2	2	5	5	1	1	8	8	29	29	21.8	22.2
Hawaii	1	1	1	1	--	--	2	2	2	2	1.8	1.8
Puerto Rico	2	2	--	--	--	--	2	2	9	9	7.3	7.4
Total or average	89	88	61	61	7	8	157	157	380	377	286.6	290.3

District	Average number of days for maintenance 1978	Average number of days for maintenance 1979	Apparent annual capacity[3] (thousand short tons) 1978	Apparent annual capacity[3] (thousand short tons) 1979	Production[4] (thousand short tons) 1978	Production[4] (thousand short tons) 1979	Percent utilized 1978	Percent utilized 1979
New York and Maine	53	72	4,960	4,630	3,951	4,061	79.7	87.7
Pennsylvania, eastern	41	52	6,540	5,980	4,629	4,827	70.8	80.7
Pennsylvania, western	33	52	2,421	2,376	1,901	1,882	78.5	79.2
Maryland and West Virginia	51	49	2,544	2,592	2,210	2,305	86.9	88.9
Ohio	59	41	2,295	2,751	1,935	2,044	84.3	74.3
Michigan	37	34	5,513	5,562	5,004	4,738	90.8	85.2
Indiana	71	65	3,055	3,182	2,269	2,424	74.3	76.2
Illinois	38	43	3,039	3,320	2,027	2,036	66.6	61.3
Tennessee	42	51	1,744	2,074	1,519	1,455	87.1	70.2
Kentucky, North Carolina, Virginia	45	44	2,174	2,217	1,785	1,781	82.1	80.3
South Carolina	53	71	2,277	2,148	2,028	2,050	89.1	95.4
Florida	59	74	3,463	3,287	2,703	2,804	78.1	85.3
Georgia	35	44	1,582	1,543	1,364	1,324	86.2	85.8
Alabama	72	55	3,370	3,628	3,056	3,103	90.7	85.5
Louisiana and Mississippi	64	61	1,684	1,701	1,460	1,501	86.7	88.2
Nebraska, Wisconsin	88	44	858	994	838	953	97.6	95.9
South Dakota	73	93	962	899	545	656	56.7	73.0
Iowa	51	51	2,979	2,981	2,333	2,332	78.3	78.2
Missouri	50	55	4,823	4,744	4,348	4,253	90.2	89.7
Kansas	56	47	2,254	2,318	1,984	2,064	88.0	89.0
Oklahoma and Arkansas	38	52	2,809	2,725	2,741	2,568	97.6	94.2
Texas	52	52	8,724	8,822	7,907	8,362	90.6	94.8
Wyoming, Montana, Idaho	33	52	1,028	970	1,032	970	100.4	100.0
Colorado, Arizona, Utah, New Mexico	53	61	4,093	4,049	3,712	3,665	90.7	90.5
Washington	40	28	1,136	1,180	1,120	1,112	98.6	94.2
Oregon, Nevada	46	51	1,052	1,035	976	953	92.8	92.1
California, northern	63	70	2,873	2,770	2,404	2,361	83.7	85.2
California, southern	65	56	6,520	6,867	5,854	5,776	89.8	84.1
Hawaii	104	107	469	464	430	445	91.7	95.9
Puerto Rico	107	110	1,880	1,885	1,390	1,338	73.9	71.0
Total or average	54	56	89,121	89,694	75,455	76,143	84.7	84.9

[1] Includes Puerto Rico.
[2] Includes white cement producing facilities.
[3] Calculated on individual company data: 365 days, minus average days for maintenance, times the reported 24-hour capacity.
[4] Includes production reported for plants which added or shut down kilns during the year.

Table 5.—Daily clinker capacity, December 31[1] [2]

Short tons per 24-hour period	Number		Total capacity (short tons)	Percent of total capacity
	Plants	Kilns[3]		
1978:				
Less than 600	5	7	2,287	0.8
600 to 1,150	34	64	29,370	10.2
1,150 to 1,700	48	107	67,293	23.5
1,700 to 2,300	31	77	61,676	21.5
2,300 to 2,800	15	37	37,018	12.9
2,800 and over	24	88	89,177	31.1
Total	157	380	286,821	100.0
1979:				
Less than 600	5	7	2,271	0.8
600 to 1,150	33	59	28,792	10.0
1,150 to 1,700	49	108	69,052	23.7
1,700 to 2,300	29	70	57,868	19.9
2,300 to 2,800	16	41	39,291	13.5
2,800 and over	25	92	93,571	32.1
Total	157	377	290,845	100.0

[1] Includes Puerto Rico.
[2] Includes white cement-producing facilities.
[3] Total number in operation at plants.

Table 6.—Raw materials used in producing portland cement in the United States[1]

(Thousand short tons)

Raw materials	1978	1979
Calcareous:		
Limestone (includes aragonite, marble, chalk)	78,452	83,163
Cement rock (includes marl)	34,429	30,987
Oystershell	2,064	1,341
Argillaceous:		
Clay	6,758	7,016
Shale	4,399	4,289
Other (includes staurolite, bauxite, aluminum dross, pumice, and volcanic material)	225	362
Siliceous:		
Sand	2,806	2,128
Sandstone and quartz	710	808
Ferrous: Iron ore, pyrites, millscale, and other iron-bearing material	1,037	1,063
Other:		
Gypsum and anhydrite	4,260	4,324
Blast furnace slag	479	483
Fly ash	483	509
Other, n.e.c	22	6
Total	135,624	136,479

[1] Includes Puerto Rico.

MASONRY CEMENT

Shipments of masonry cement totaled 4.2 (3.8) million tons. The 1978 shipments exceeded the previously record high shipments of 1973 by 20,000 tons. The average unit price was $50.53 ($54.59) per ton. At yearend 1979, 105 plants were manufacturing masonry cement in the United States. During 1978 and part of 1979, four plants produced masonry cement exclusively, as follows: Cheney Lime & Cement Co., Allgood, Ala.; G. & W. H. Corson, Inc., Plymouth Meeting, Pa.; Campbell-Grove, Div. of the Flintkote Co., Frederick, Md.; and Riverton Corp., Riverton, Va. G. & W. H. Corson, Inc. stopped production of masonry cement during 1979, leaving only three exclusive producers at yearend.

In many parts of the country, masons preferred to do their own blending of portland cement. As a result masonry cement was not produced in some parts of the country.

Table 7.—Masonry cement shipped by producers in the United States, by district[1] [2]

(Thousand short tons and thousand dollars)

District	1978			1979		
	Quantity	Value	Average per ton	Quantity	Value	Average per ton
New York and Maine	86	3,209	37.31	84	3,793	45.15
Pennsylvania, eastern	282	15,023	53.27	275	16,948	61.62
Pennsylvania, western	163	7,780	47.73	141	7,229	51.26
Maryland and West Virginia	159	6,354	39.96	146	6,793	46.52
Ohio	196	10,955	55.89	170	10,869	63.93
Michigan	294	13,621	46.32	262	16,455	62.80
Illinois and Indiana	517	24,375	47.15	455	23,699	52.08
Tennessee	217	10,443	48.12	170	8,600	50.58
Kentucky, North Carolina, Virginia	268	13,153	49.26	247	13,236	53.58
Florida	232	13,124	56.56	255	13,098	51.36
Georgia	105	4,849	46.18	102	5,172	50.70
Alabama	357	17,293	48.57	303	13,930	45.97
Louisiana, Mississippi, South Carolina	325	16,904	52.01	291	16,420	56.42
Nebraska and Wisconsin	21	1,509	71.85	21	1,513	72.04
South Dakota	9	492	54.66	7	434	62.00
Iowa	88	5,390	61.25	69	3,844	55.71
Missouri	89	4,112	46.20	82	4,159	50.71
Kansas	96	4,558	47.47	89	4,525	50.84
Oklahoma and Arkansas	145	7,202	49.66	128	7,000	54.68
Texas	290	17,248	59.47	268	15,593	58.18
Wyoming, Montana, Idaho	11	732	66.54	11	702	63.81
Colorado, Arizona, Utah, New Mexico	153	8,689	56.79	150	8,892	59.28
Washington	9	626	69.55	10	741	74.10
Oregon and Nevada	1	75	75.00	1	64	64.00
California, northern	--	22	--	--	--	--
California, southern	--	--	--	--	--	--
Hawaii	11	828	75.27	12	1,086	90.50
Puerto Rico	--	--	--	--	--	--
U.S. total or average[3]	4,124	208,566	50.57	3,748	204,797	54.63
Foreign imports[4]	26	1,135	43.65	14	637	45.50
Total or average	4,150	209,701	50.53	3,762	205,434	54.59

[1] Does not include quantities produced on the job by masons.

[2] Includes Puerto Rico.

[3] Data may not add to totals shown because of independent rounding.

[4] Cement imported and distributed by domestic producers only. Source of imports withheld to avoid disclosing company proprietary data.

Table 8.—Masonry cement production and stocks in the United States, by district[1]

(Thousand short tons)

District	1978			1979		
	Plants active during year	Production	Stocks[2] at mills Dec. 31	Plants active during year	Production	Stocks[2] at mills Dec. 31
New York and Maine	3	81	7	3	86	10
Pennsylvania, eastern	9	270	20	9	285	26
Pennsylvania, western	5	163	17	5	144	21
Maryland and West Virginia	3	166	6	3	149	11
Ohio	4	189	9	4	178	18
Michigan	5	284	62	5	278	77
Illinois and Indiana	5	520	48	4	464	56
Tennessee	5	239	16	5	173	15
Kentucky, North Carolina, Virginia	4	263	11	4	255	20
Florida	4	237	11	4	267	9
Georgia	3	80	11	3	108	12
Alabama	6	355	23	6	308	29
Louisiana, Mississippi, South Carolina	4	321	18	4	280	18
Nebraska and Wisconsin	3	22	4	3	20	3
South Dakota	1	14	6	1	3	3
Iowa	3	84	5	3	77	15
Missouri	4	83	7	4	83	9
Kansas	5	103	15	5	88	14
Oklahoma and Arkansas	5	144	7	5	131	9
Texas	11	297	19	11	269	27
Wyoming, Montana, Idaho	3	13	4	4	11	3
Colorado, Arizona, Utah, New Mexico	6	152	7	5	154	10
Washington	3	10	2	3	12	4
Oregon and Nevada	--	--	(3)	--	--	(3)
California, northern	--	--	(3)	--	--	--
California, southern	--	--	--	--	--	--
Hawaii	2	12	4	2	10	2
Puerto Rico	--	--	--	--	--	--
Total	106	[4]4,102	339	105	[4]3,833	421

[1] Includes Puerto Rico.

[2] Includes imported cement.

[3] Less than 500 short tons.

[4] Includes 3,360 tons produced from clinker, and 742 tons produced from cement (1978); 3,129 tons produced from clinker, and 704 tons produced from cement (1979).

ALUMINOUS CEMENT

Aluminous cement, also known as calcium aluminate cement, high-alumina cement, and "Ciment Fondu," is a nonportland hydraulic cement. It was produced at the following three plants in the United States: United States Steel Corp., Universal Atlas Cement Div., Buffington, Ind.; Lone Star Lafarge Co. at Chesapeake, Va.; and Aluminum Co. of America at Bauxite, Ariz.

As previously discussed, Lone Star brought online its new plant at Chesapeake, Va., during 1978.

ENERGY

High energy cost and its availability have been an industry concern since 1974. Much progress has been made toward lowering the amount of energy required to produce a ton of finished cement. Many older plants have been converted from wet-process to dry-process systems, some have been converted to burn coal as a primary fuel source, and preheaters and precalciners have been installed in new and modernized plants. These were some of the approaches that the cement industry used in their attempts to reduce the overall energy consumption per ton of cement by 15.7% by January 1, 1980, as targeted by the U.S. Department of Energy on June 9, 1977. The base year in the U.S. Government's voluntary energy conservation program is 1972. Data show that U.S. producers did not achieve the goal. Energy consumption per ton of production was reduced by 9.8% in 1978 and 8.2% in 1979. In the United States, coal accounted for 69% (72%) of total kiln fuel consumption, compared with 41% in 1972.

Coal is the one energy source that the United States has in abundance and it is the major alternative to oil or natural gas. Several companies have reported on programs involving conversions to coal as a prime fuel in their kiln systems. Ideal Basic Industries noted that all but one plant is capable of using coal as kiln fuel. Only the Mobile, Ala., kilns used natural gas or oil and this plant was scheduled to be closed once the new Theordore, Ala., plant comes online. Their new Knoxville, Tenn. dry-process plant, equipped with a preheater and precalciner, was coal-fired and consumed less than 4 million Btu's to produce 1 ton of clinker. At the Boetcher, Colo. plant, a traveling grate preheater allows kerogen, contained in a natural limestone admixture, to become part of the fuel mixture and thus results in a savings of one-fourth the normal amount of fuel required. Average fuel consumption has been reduced at Ideal plants by 13% using 1972 as the base year.[5]

Lone Star Industries, Inc., spent $5 million to convert its Maryneal, Tex., plant from natural gas to coal. Startup occurred in early spring 1979.

Gifford-Hill & Co., Inc., completed coal conversion construction at both its Midlothian, Tex. and Harleyville, S.C. cement plants. Coal at these plants was to be hauled by railcars and stored in stockpiles.[6]

Alpha Portland Industries, Inc., with the conversion of its Orange, Tex. kiln to coal, had five of its six plants burning coal as a primary fuel. During 1975-77, the company had been experimenting with burning industrial wastes in the Jamesville, N.Y. kiln. Since the process was wet, it provided an ideal means of disposing of certain liquid wastes. Alpha had found the cost of energy received in the form of such wastes is much lower than the cost of equivalent energy found in traditional fuels. Based on experiences at Jamesville, the company is installing facilities to handle similar materials at its Birmingham, Ala. and St. Louis, Mo. plants.[7]

Several cement companies were involved with developing coal properties during this reporting period. Amcord Inc., announced that it would spend $12 million adding to its present coal mining capacity at its mine near Gallup, N. Mex., increasing production from 150,000 to 400,000 tons per year. Its Lucas Coal Co. mine in Grove City, Pa., was to increase output from 230,000 to 600,000 tons per year.[8]

California Portland Cement Co. undertook an option to a long-term coal mining lease covering 960 acres of coal-bearing property in Southern Utah, owned by Ivie Creek Coal Co. The property has 20 years of recoverable coal reserves.[9]

Kaiser Cement Corp. applied to the Texas Railroad Commission for a permit to mine coal at a leased 3,500-acre site in Coleman County, Tex. Proven reserves were 3 million tons, and coal from this deposit was to be used at the San Antonio, Tex. plant. Mining was to be done by a wholly owned subsidiary, Armistad Fuel. Annual production was to be 200,000 to 300,000 tons.[10]

Texas Industries, Inc. planned to use coal as its principal fuel source at its new plant at Hunter, Tex.

The Flintkote Co.'s Calaveras Cement Div. reported that they converted the fuel source for their San Andreas and Redding, Calif. plants from natural gas to coal. Bituminous coal was mined near Salina, Utah by Coastal States Energy Co. and shipped by rail over the Sierras to the San Andreas and Redding plants. New coal systems at the two plants cost over $5.5 million.[11]

During 1978-79, total energy from fossil fuels consumed by the cement industry in clinker manufacture was about 422 (427) billion Btu's. Of these amounts, 291 (306) billion Btu's were derived from coal; 86 (88) billion Btu's from natural gas; and 45 (32) billion Btu's from fuel oil. Total tonnage consumption of coal by the industry in 1979 was 5% more than it had been in 1978. Consumption by the industry of natural gas in 1979 was 87.8 billion cubic feet, a 4% increase in usage compared with that of 1978.

Energy from fossil fuels consumed in cement plants to produce clinker average 5.6 million Btu's per ton for each of the 2 years ranging from 12.8 million to 2.9 million (12.5 million to 2.3 million) Btu's per ton. These figures show a decline compared with those of 1977, when the average was 6.3 million Btu's per ton, ranging from 12.9 to 3.4 million Btu's per ton. Decreased energy consumption could be related to decreased use and retirement of older kilns. On the average, wet-process plants were less energy efficient; average consumption nationwide was 6.1 (6.3) million Btu's per ton, compared with 4.9 (4.8) million Btu's for dry-process kilns. Kilns without preheaters averaged 5.8 (5.9) million Btu's per ton; those with suspension preheaters averaged 4.8 (4.6) million Btu's per ton, and those with grate-type preheaters averaged 5.3 (5.1) million Btu's per ton of clinker produced.

Electrical energy consumed in the manufacture of cement totaled 11.3 (11.4) billion kilowatt-hours, 10.7 (10.8) billion of which was purchased commercially and 0.6 (0.6) billion was generated on site. The average amount of electrical energy used to produce 1 ton of cement was 139.0 (139.4) kilowatt-hours, just about the same kilowatt-hours required in 1977. This energy, used principally for grinding operations, added nearly another 0.5 Btu's of energy required to manufacture 1 ton of cement.

Pozzolanic additives are another means of conserving energy, receiving increased attention in recent years. During 1978, the U.S. Department of Energy released an interim report on the performance of blended cements in concrete with emphasis on the potential offered by these cements for reducing energy consumption in cement manufacture. Blended cements are hydraulic cements composed of mixtures of conventional portland cement with additions that are either themselves capable of hydraulic setting (certain metallurgical slags) or are pozzolanic (such as flyash). Although less than 1% of the cement produced in the United States was blended cement, it was much higher in other industrialized nations. For example, in France, blended cements accounted for about 60% of the total production. Many factors have worked against increased production of blended cement in the United States, some of which are low fuel costs in the past; abundance of raw material supplies; lack of dissemination of technical information on utilization and engineering performance; uncertainty about sustained availability, uniformity, and quality of additives; and satisfaction with portland cement.

Flyash caused more interest than slag as an additive to cement as well as to concrete. At the Ash Management Conference, Texas A&M University, College Station, Tex., held in September 1978, a number of papers were presented on portland-flyash cement and concrete ranging from mixture design to construction control and handling. Blended cements had been an important topic at a workshop held at the National Bureau of Standards, Gaithersburg, Md., in late 1977. Emphasis was directed toward the possible contributions of cement and concrete technology to energy conservation by 2000.

During 1978-79, shipments of Types IP and IS cement totaled 1.1 (1.0) million tons, little more than 1% of total portland cement shipments in each of the 2 years. This represented an increase of over 200% compared with that of 1977.

Table 9.—Clinker produced in the United States, by kind of fuel[1]

Year and fuel	Clinker produced: Plants active during year	Clinker produced: Quantity (thousand short tons)	Clinker produced: Percent of total	Fuel consumed: Coal[2] (thousand short tons)	Fuel consumed: Oil (thousand 42-gallon barrels)	Fuel consumed: Natural gas (thousand cubic feet)
1978:						
Coal	40	[3]18,512	24.5	4,196	--	--
Oil	6	[3]2,594	3.4	--	2,373	--
Natural gas	8	[3]2,747	3.7	--	--	15,336,542
Coal and oil	19	10,042	13.3	2,040	704	--
Coal and natural gas	49	21,038	27.9	3,517	--	37,010,210
Oil and natural gas	11	7,085	9.4	--	3,100	20,314,524
Coal, oil, natural gas	24	13,437	17.8	2,537	1,026	11,618,170
Total	157	75,455	100.0	12,290	7,208	84,279,446
1979:						
Coal	41	[3]19,339	25.4	4,499	--	--
Oil	6	[3]2,578	3.4	--	2,316	--
Natural gas	6	[3]2,011	2.6	--	--	11,863,215
Coal and oil	16	8,948	11.8	1,741	549	--
Coal and natural gas	53	23,359	30.7	4,414	--	37,404,465
Oil and natural gas	10	6,775	8.9	--	1,333	29,304,201
Coal, oil, natural gas	25	13,133	17.2	2,290	816	9,239,488
Total	157	76,143	100.0	12,944	5,014	87,811,369

[1] Includes Puerto Rico.

[2] Includes 97.5% bituminous, and 2.5% petroleum coke.

[3] Average consumption of fuel per ton of clinker produced as follows: 1978-coal, 0.22666 ton; oil, 0.915 barrel; and natural gas, 5,583 cubic feet. 1979-coal, 0.23263 ton; oil, 0.898 barrel; and natural gas, 5,899 cubic feet.

Table 10.—Clinker produced and fuel consumed by the portland cement industry in the United States, by process[1]

Year and process	Clinker produced			Fuel consumed		
	Plants active during year	Quantity (thousand short tons)	Percent of total	Coal[2] (thousand short tons)	Oil (thousand 42-gallon barrels)	Natural gas (thousand cubic feet)
1978:						
Wet	89	40,558	53.8	6,854	5,035	51,364,391
Dry	61	30,619	40.6	4,931	1,672	22,874,924
Both	7	4,278	5.6	505	496	10,040,131
Total	157	75,455	100.0	12,290	7,203	84,279,446
1979:						
Wet	88	40,285	52.9	7,286	3,579	54,744,897
Dry	61	31,076	40.3	5,058	1,345	20,342,502
Both	8	4,782	6.3	600	90	12,723,970
Total	157	76,143	100.0	12,944	5,014	87,811,369

[1] Includes Puerto Rico.

[2] Includes 97.5% bituminous, and 2.5% petroleum coke in both 1978 and 1979.

Table 11.—Electric energy used at portland cement plants in the United States, by process[1][2]

Year and process	Electric energy used						Finished cement produced (thousand short tons)	Average electric energy used per ton of cement produced (kilowatt-hours)
	Generated at portland cement plants		Purchased		Total			
	Active plants	Quantity (million kilowatt-hours)	Active plants	Quantity (million kilowatt-hours)	Quantity (million kilowatt-hours)	Percent		
1978:								
Wet	3	101	87	5,539	5,640	49.8	43,878	128.5
Dry[3]	5	533	68	4,497	5,030	44.5	33,196	151.5
Both	--	--	7	641	641	5.7	4,305	149.9
Total	8	634	162	10,677	11,311	100.0	81,379	139.0
Percent of total electric energy used	--	5.6	--	94.4	--	--	--	--
1979:								
Wet	4	126	86	5,536	5,662	49.5	43,694	129.6
Dry[3]	4	475	68	4,585	5,060	44.2	33,558	150.8
Both	--	--	8	718	718	6.3	4,819	149.9
Total	8	601	162	10,839	11,440	100.0	82,071	139.4
Percent of total electric energy used	--	5.3	--	94.7	--	--	--	--

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[1] Includes grinding plants and white cement facilities.
[2] Includes Puerto Rico.
[3] Includes data for grinding plants.

TRANSPORTATION

At the 1978 spring meeting of the National Association of Cement Shippers (NACS) in New York, a Conrail official noted that shipment of cement is not profitable enough to cause railroads either to seek this business or to allocate cars for it. To make a 15% profit on a 60-ton pressure differential (PD) car, $8,400 annually was required. In 1977, Conrail carried 1.6 million tons of cement valued at $10.4 million dollars; in 1970, Conrail's predecesser, the Penn-Central System, had carried 2.5 million tons.[12] At the 1978 fall meeting of the NACS, an official with the Bureau of Operations, Interstate Commerce Commission, noted that the railcar shortage in 1978 was the most severe on record.[13] National average daily shortages for all types of freight cars reached a high of 66,000 cars during April 1978, including 37,000 covered hopper cars and 10,000 plain hopper cars. Some reasons for the shortages included poor car utilization, insufficient locomotives, poor maintenance of the entire railroad operation, and extremely heavy inventories of unserviceable railcars.

Rail is an important transportation mode in transferring cement from the producing plant to distant distribution terminals especially when isolated regional cement shortages occur. To counteract the problems of an inadequate railcar supply, several cement companies have entered long term-lease arrangements with railcar leasing firms. Dundee Cement Co., Dundee, Mich., added 150 additional covered hopper cars to carry its products to customers and terminals throughout mid-America. Fifty cars were obtained from Chicago Freight Car Leasing for a 5-year period, and 100 cars were obtained from North American Car Corp. on a 12-year lease.[14]

Waterway systems are also an important mode for transporting cement from manufacturing plants to distribution terminals. Medusa Corp. gave this as a justification to expand and modernize its Charlevoix, Mich. plant on Lake Michigan.[15] Dundee Cement Co. modified its Minneapolis, Minn., terminal dock by installing an unloading nozzle similar to the one it placed in service in Chicago in 1976.[16] The nozzle makes it possible to unload leased roll-top barges as well as Dundee barges.

Although railroads and barges transported most cement shipments from manufacturing plants to distribution terminals, trucks continued in the lead as the most economical method for transporting cement to the customer. Trucks hauled 89% of the cement shipments to ultimate consumers in each of the 2 years, railroads handled 9%, and 1% was moved by waterway. This represented little change from 1977.

Table 12.—Shipments of portland cement from mills in the United States, in bulk and in containers, by type of carrier[1]

(Thousand short tons)

Year and type of carrier	Shipments from plant to terminal		Shipments to ultimate consumer				
			From terminal to consumer		From plant to consumer		Total shipments
	In bulk	In containers	In bulk	In containers	In bulk	In containers	
1978:							
Railroad	7,164	166	798	26	6,680	273	7,777
Truck	1,313	88	16,815	903	51,754	5,299	74,771
Barge and boat	8,353	13	111	3	728	41	883
Unspecified[2]	5	--	13	1	388	16	418
Total	16,835	267	17,737	933	59,550	5,629	[3]83,849
1979:							
Railroad	7,372	192	753	27	6,085	186	7,051
Truck	1,252	78	17,356	1,021	51,394	5,142	74,913
Barge and boat	8,638	49	49	33	614	38	734
Unspecified[2]	4	--	59	3	590	40	692
Total	17,266	319	18,217	1,084	58,683	[4]5,405	[3]83,390

[1] Includes Puerto Rico.

[2] Includes cement used at plant.

[3] Bulk shipments were 92.2% (77,287 tons), and container (bag) shipments were 7.8% (6,562 tons) for 1978. Bulk shipments were 92.2% (76,900 tons), and container (bag) shipments were 7.8% (6,490 tons) for 1979.

[4] Data may not add to totals shown because of independent rounding.

Table 13.—Cement shipments, by destination and origin[1]

(Thousand short tons)

	Portland cement[2]		Masonry cement	
	1978	1979	1978	1979
Destination:				
Alabama	1,498	1,270	141	116
Alaska[3]	116	90	W	--
Arizona	1,617	1,808	W	W
Arkansas	952	892	75	62
California, northern	3,430	3,813	(4)	1
California, southern	5,327	5,734	7	13
Colorado	1,517	1,515	42	40
Connecticut[3]	769	766	15	16
Delaware[3]	140	155	9	8
District of Columbia[3]	170	126	7	5
Florida	4,260	4,602	360	396
Georgia	2,207	2,100	202	189
Hawaii	381	422	11	12
Idaho	459	471	2	2
Illinois	3,666	3,378	142	133
Indiana	1,792	1,713	134	114
Iowa	1,923	1,779	33	28
Kansas	1,234	1,294	33	29
Kentucky	1,224	1,231	139	116
Louisiana	2,848	2,755	108	91
Maine	260	242	12	12
Maryland	1,386	1,358	126	122
Massachusetts[3]	982	1,005	40	42
Michigan	2,936	2,874	183	169
Minnesota	1,764	1,714	66	58
Mississippi	1,020	947	86	76
Missouri	2,094	1,863	59	51
Montana	362	335	4	4
Nebraska	974	1,053	20	19
Nevada	612	610	1	(4)
New Hampshire[3]	336	307	11	11
New Jersey[3]	1,693	1,727	69	69
New Mexico	633	583	15	10
New York, eastern	738	776	30	29
New York, western	942	885	47	41
New York, metropolitan[3]	838	916	32	35
North Carolina	1,781	1,656	258	227
North Dakota[3]	357	371	10	9
Ohio	3,429	3,202	242	208
Oklahoma	1,659	1,699	80	69
Oregon	967	976	2	1
Pennsylvania, eastern	1,917	1,797	79	71
Pennsylvania, western	1,122	1,105	109	94
Puerto Rico	1,442	1,343	--	--
Rhode Island[3]	160	159	5	6
South Carolina	939	926	141	123
South Dakota	344	411	10	8
Tennessee	1,519	1,515	210	172
Texas	8,603	8,745	275	251
Utah	900	921	3	2
Vermont[3]	148	138	6	5
Virginia	1,885	1,973	226	191
Washington	1,633	1,846	11	11
West Virginia	614	580	59	51
Wisconsin	1,874	1,766	78	64
Wyoming	385	462	4	4
Total United States	84,773	84,700	4,069	3,686
Foreign countries[5]	65	160	106	109
Total shipments	84,838	84,860	4,175	3,795
Origin:				
United States[6]	80,009	78,978	4,124	3,749
Puerto Rico	1,442	1,406	--	--
Foreign:[7]				
Domestic producers	2,398	3,006	26	14
Others	989	1,470	25	32
Total shipments	84,838	84,860	4,175	3,795

W Withheld to avoid disclosing company proprietary data; included with "Foreign countries."

[1] Includes cement produced from imported clinker and imported cement shipped by domestic producers, Canadian cement manufacturers, and other importers. Includes Puerto Rico.

[2] Excludes cement (1978—428; 1979—425) used in the manufacture of prepared masonry cement.

[3] Has no cement-producing plants.

[4] Less than 500 short tons.

[5] Direct shipments by producers to foreign countries and U.S. possessions and territories; includes States indicated by symbol W.

[6] Includes cement produced from imported clinker by domestic producers.

[7] Imported cement distributed by domestic producers, Canadian cement manufacturers, and other importers. Origin of imports withheld to avoid disclosing company proprietary data.

Table 14.—Portland cement shipments, by type of customer[1]

(Thousand short tons)

District Origin	Building material dealers		Concrete product manufacturers		Ready-mixed concrete		Highway contractors		Other contractors		Federal, State, and other government agencies		Miscel- laneous including own use		Total[2]
	Quan- tity	Per- cent	Quan- tity	Per- cent	Quan- tity	Per- cent	Quan- tity	Per- cent	Quan- tity	Per- cent	Quan- tity	Per- cent	Quan- tity	Per- cent	
1978:															
New York and Maine	227	5.4	730	17.5	2,869	68.7	54	1.3	130	3.1	1	(3)	168	4.0	4,180
Pennsylvania, eastern	573	11.9	1,219	25.4	2,731	56.9	131	2.7	97	2.0	4	(3)	51	1.1	4,805
Pennsylvania, western	213	11.0	669	34.4	868	44.6	84	4.3	63	3.2	4	0.2	44	2.3	1,945
Maryland and West Virginia	136	5.9	482	21.0	1,574	68.4	32	1.4	75	3.3	1	(3)	1	(3)	2,300
Ohio	179	8.9	345	17.1	1,364	67.5	108	5.3	9	.4	1	(3)	16	.8	2,022
Michigan	346	5.9	890	15.0	3,930	66.4	643	10.9	81	1.4	24	.4	2	(3)	5,917
Indiana	200	8.2	456	18.8	1,586	65.4	133	5.5	45	1.9	8	.1	4	.1	2,426
Illinois	111	5.3	154	7.3	1,684	79.7	117	5.5	27	1.3	--	--	20	.9	2,113
Tennessee	147	9.4	337	21.5	916	58.4	48	3.1	14	.9	49	3.1	57	3.6	1,568
Kentucky, North Carolina, Virginia	114	6.1	199	10.6	1,329	71.0	121	6.5	82	4.4	1	.1	24	1.3	1,871
South Carolina	56	2.9	308	15.9	1,470	75.8	65	3.4	28	1.4	2	(3)	12	.6	1,940
Florida	410	14.9	237	8.5	1,695	61.3	198	7.2	167	6.0	45	1.6	14	.5	2,766
Georgia	87	6.1	237	16.5	706	49.2	219	15.2	149	10.4	7	.5	31	2.1	1,435
Alabama	254	9.0	516	18.2	1,857	65.5	113	4.0	72	2.5	4	.1	21	.7	2,837
Louisiana and Mississippi	196	12.1	139	8.5	898	55.2	98	6.0	148	9.1	98	6.0	51	3.1	1,628
Nebraska and Wisconsin	68	6.1	141	12.5	736	65.4	158	14.1	10	.9	2	.2	9	.8	1,125
South Dakota	26	4.8	44	8.1	325	59.7	118	21.7	28	5.1	1	.2	2	.4	545
Iowa	98	3.7	518	19.6	1,810	68.4	201	7.6	13	.5	1	(3)	6	.2	2,646
Missouri	131	2.8	448	9.4	3,667	77.5	399	8.4	84	1.8	--	--	4	.1	4,733
Kansas	119	5.7	123	5.9	1,615	77.5	85	4.1	83	4.0	--	--	58	2.8	2,083
Oklahoma and Arkansas	188	6.7	254	9.1	1,931	69.2	235	8.4	164	5.9	1	(3)	19	.7	2,791
Texas	809	9.2	808	9.2	5,295	60.1	333	3.8	1,152	13.1	103	1.1	307	3.5	8,808
Wyoming, Montana, Idaho	29	2.7	74	6.8	798	73.6	32	2.9	104	9.6	5	.5	42	3.9	1,085
Colorado, Arizona, Utah, New Mexico	339	8.6	387	9.8	2,745	69.6	134	3.4	249	6.3	1	(3)	90	2.3	3,945
Washington	49	2.8	219	12.4	1,312	74.5	44	2.5	79	4.5	1	.1	56	3.2	1,760
Oregon and Nevada	40	4.0	83	8.2	817	81.3	19	1.9	41	4.1	1	.1	4	.4	1,005
California, northern	258	9.0	476	16.6	1,878	65.6	75	2.6	164	5.7	1	(3)	13	.5	2,866
California, southern	533	8.3	818	12.8	4,676	72.8	105	1.6	245	3.8	6	.1	40	.6	6,423
Hawaii	12	2.7	7	1.6	365	82.8	--	--	16	3.6	1	.2	40	9.1	441
Puerto Rico	613	42.5	125	8.7	685	47.5	--	--	14	1.0	3	.2	2	.1	1,442

Imports[4]	74	3.1	112	4.7	2,073	86.4	23	.9	110	4.6	--	--	7	.3	2,398
Total or average	6,635	7.9	11,555	13.8	56,205	67.0	4,125	4.9	3,743	4.5	371	.4	1,215	1.5	83,849
1979:															
New York and Maine	1,289	31.3	674	16.4	1,795	43.5	102	2.5	88	2.1	1	([3])	174	4.2	4,123
Pennsylvania, eastern	599	12.8	1,255	26.9	2,591	55.5	125	2.7	75	1.6	6	.1	17	.4	4,667
Pennsylvania, western	114	6.2	292	15.9	1,231	66.9	108	5.9	69	3.7	1	([3])	26	1.4	1,841
Maryland and West Virginia	108	4.7	476	20.9	1,534	67.3	81	3.6	71	3.1	2	.1	8	.3	2,280
Ohio	142	7.4	365	19.0	1,359	70.8	37	1.9	11	.6	--	--	6	.3	1,921
Michigan	396	7.0	889	15.6	3,728	65.6	538	9.5	108	1.9	23	.4	--	--	5,683
Indiana	160	6.7	417	17.4	1,653	69.2	100	4.2	55	2.3	2	.1	2	.1	2,389
Illinois	102	5.4	192	10.2	1,460	77.3	125	6.6	9	.5	--	--	1	([3])	1,889
Tennessee	123	9.2	288	21.6	776	58.2	11	.8	38	2.9	79	5.9	19	1.4	1,335
Kentucky, North Carolina, Virginia	112	6.3	201	11.3	1,272	71.6	92	5.2	69	3.9	2	.1	28	1.6	1,775
South Carolina	51	2.8	279	15.2	1,395	76.2	41	2.3	62	3.4	1	.1	--	--	1,831
Florida	437	14.8	399	13.5	1,638	55.4	239	8.1	157	5.3	63	2.1	24	.8	2,957
Georgia	89	6.7	239	17.9	703	52.7	158	11.8	133	10.0	6	.4	7	.5	1,335
Alabama	237	9.2	528	20.5	1,666	64.6	78	3.0	52	2.0	4	.2	12	.5	2,578
Louisiana and Mississippi	255	16.3	194	12.4	779	49.9	135	8.6	51	3.3	97	6.2	52	3.3	1,563
Nebraska and Wisconsin	69	5.7	141	11.6	835	68.5	163	13.4	8	.6	2	.2	--	--	1,218
South Dakota	22	3.3	43	6.4	427	63.7	127	19.0	49	7.3	--	--	2	.3	670
Iowa	93	3.9	470	19.8	1,622	68.4	104	4.4	81	3.4	--	--	2	.1	2,371
Missouri	131	3.0	466	10.5	3.412	77.0	302	6.8	112	2.5	--	--	7	.2	4,430
Kansas	109	5.2	124	5.9	1,617	77.5	75	3.6	133	6.4	--	--	29	1.4	2,086
Oklahoma and Arkansas	195	7.2	240	8.9	1,876	69.4	209	7.7	153	5.7	10	.4	20	.7	2,702
Texas	702	7.5	788	8.4	5,928	63.4	349	3.8	1,209	12.9	113	1.2	264	2.8	9,353
Wyoming, Montana, Idaho	51	4.9	78	7.4	706	67.2	45	4.3	139	13.2	22	2.1	9	.9	1,050
Colorado, Arizona, Utah, New Mexico	220	5.5	541	13.5	2,788	69.8	79	2.0	263	6.6	2	([3])	103	2.6	3,996
Washington	47	2.7	212	12.0	1,282	72.8	53	3.0	101	5.7	1	.1	65	3.7	1,761
Oregon and Nevada	39	4.0	71	7.2	773	78.8	25	2.6	67	6.8	3	.3	3	.3	981
California, northern	271	9.4	492	17.0	1,836	63.4	31	1.1	238	8.2	1	([3])	25	.9	2,894
California, southern	540	7.9	956	14.0	4,932	72.2	126	1.8	244	3.6	7	.1	25	.4	6,830
Hawaii	24	5.1	55	11.7	327	69.7	--	--	37	7.8	1	.2	26	5.5	469
Puerto Rico	582	41.4	123	8.7	616	43.8	--	--	18	1.3	4	.3	64	4.5	1,406
Imports[4]	117	3.9	297	9.9	2,378	79.1	91	3.0	22	.8	85	2.8	15	.5	3,006
Total or average	7,426	8.9	11,785	14.1	54,985	65.9	3,749	4.5	3,922	4.7	538	.7	1,085	1.2	83,390

[1] Includes Puerto Rico.
[2] Data may not add to totals shown because of independent rounding.
[3] Less than 0.1%.
[4] Cement imported and distributed by domestic producers only. Source of imports withheld to avoid disclosing company proprietary data.

Table 15.—Portland cement shipped from plants in the United States, by type[1]

(Thousand short tons and thousand dollars)

Type	1978 Quantity	1978 Value[2]	1978 Average per ton	1979 Quantity	1979 Value[2]	1979 Average per ton
General use and moderate heat (Types I and II)	76,841	3,085,174	$40.15	76,392	3,487,564	$45.65
High-early-strength (Type III)	2,817	111,992	39.76	2,712	123,172	45.42
Sulfate-resisting (Type V)	235	12,082	51.41	202	11,197	55.43
Oil well	1,680	79,065	47.06	1,922	100,935	52.52
White	390	39,181	100.46	400	44,125	110.31
Portland slag and portland pozzolan	1,099	45,693	41.57	997	46,909	47.05
Expansive	86	4,024	46.79	103	5,293	51.39
Miscellaneous[3]	701	36,063	--	662	37,151	--
Total or average	83,849	3,413,274	40.70	83,390	3,856,346	46.24

[1] Includes Puerto Rico.

[2] Mill value is the actual value of sales to customers, f.o.b. plant, less all discounts and allowances, less all freight charges to customer, less all freight charges from producing plant to distribution terminal if any, less total cost of operating terminal if any, less cost of paper bags and pallets.

[3] Includes waterproof cement and low-heat (Type IV).

CONSUMPTION AND USES

Shipments of cement into various States are considered to be an index of consumption. Portland cement consumption for 1978-79 increased 8% above that of 1977. Domestic producers shipped 83.8 (83.4) million tons of portland cement, which included 2.4 (3.0) million tons of imported cement. In addition to the imported cement shipped by domestic manufacturers, 989,000 (1,470,000) tons of portland cement were imported and shipped or used by others not producing cement in the United States or Puerto Rico.

Compared with 1977, consumption in 1978 increased in all but seven States and Metropolitan New York. States showing large decreases in consumption were in West North-central and North Mountain regions of the United States as follows: North Dakota, 17%; Idaho, 10%; and South Dakota, 7%. Those States with large increases in consumption were in New England and the Middle Atlantic States as follows: New Hampshire, 27%; New Jersey, 27%; and Connecticut, 19%. In 1979, total consumption remained about the same as in 1978, but geographic shifts occurred. Twenty-four States plus the District of Columbia, western New York, and Puerto Rico showed decreases in consumption, with the largest percent decreases occurring in the District of Columbia (26%), Alaska (22%), Alabama (15%), and Missouri (11%). Eighteen States plus eastern and Metropolitan New York showed increases in consumption. Those States showing the largest increases in 1979 were Wyoming (20%), South Dakota (19%), Washington (13%), Arizona (12%), Hawaii (11%), Delaware (11%), and California (9%).

Ready-mix concrete producers were the primary consumers of portland cement, accounting for 67% (64%) of the total quantity shipped by domestic producers. Manufacturers of concrete products used 13.8% (14.1%) of the cement to produce concrete blocks, pipe, precast, prestressed, and other concrete products. Highway contractors consumed 4.9% (4.5%); building contractors, 7.9% (8.9%); and Federal, State, and other government agencies plus other miscellaneous users consumed the remaining cement shipments.

Construction was unexpectedly strong in most sectors. In 1978, housing starts were about 2 million units, consisting of 1.45 million single-units and 0.55 million multiunits. In 1979, the number of housing units dropped to 1.74 million, with 1.19 million being single units, and multiunits remaining at 0.55 million.[17]

According to the F.W. Dodge Div. of McGraw-Hill Inc., the dollar volume of construction contracting was $74.5 ($74.7) billion for residential buildings, $44.4 ($49.7) billion for nonresidential buildings, and $39.5 ($42.0) billion for nonbuilding construction. When all construction categories are included, construction spending in 1979 increased 5% in dollar volume, going from $158.4 billion in 1978 to $166.4 billion in 1979.

The Ready-mix Concrete Association reported that the ready-mix concrete industry produced 225 (220) million cubic yards, just 1.5% (4%) short of the alltime high of 228.5 million cubic yards in 1973. Value of sales exceeded $6.7 ($7.6) billion.

Reflecting increasing new applications for cement in construction is the fact that over the last 20 years cement consumption has risen at an average annual rate of about 2.3%. This is a slightly faster trend than that of construction put in place (as measured in constant dollars).[18]

Some of the more noteworthy newer applications of cement in construction in 1978 included the use of two giant conveyors to place a record amount of soil-cement for slope protection and interior dikes in a 7,000-acre cooling water reservoir for a nuclear powerplant near Matagordo County, Tex. In a tight 15-month schedule, 1.4 million cubic yards of soil-cement were put in place. Another growing application is shotcreting. An interesting concrete use in mines was reported in Mining Magazine citing an experience in a South African platinum mine. Concrete sausage-shaped support pillars 3 meters long, 0.6 meters wide, and between 70 and 80 centimeters high were used to replace conventional timber supports. The concrete sausages consisted of bags filled with a grout of portland or slag cement and sand in the ratio of 1:2 and were installed in a staggered pattern.

Growing in importance is the use of concrete overlays in highway work. Vast stretches of U.S. highways are in dire need of rehabilitation.

Making news in 1978 was the first high-strength concrete tower for New York. The Palace, a 51-story luxury hotel, used 8,000-pound-per-square-inch-strength concrete allowing the use of 20% to 25% smaller columns compared with conventional mixes.

Examples of concrete being selected over steel for structural use include a prestressed concrete frame and precast panel system for a North Carolina building and concrete box girders for Michigan's four-lane Zilwaukee Bridge across the Saginaw River.

One other new and unique use of concrete was the Office of Surface Mining's grant of $1 million to fill underground mine tunnels at Frostburg College, Frostburg, Md. Tunnels running under three buildings were to be injected with a mixture of portland cement and flyash.

Cement supply shortages were common in most parts of the Nation west of the Mississipi River throughout 1978. No one region characterized the problem. Some of the immediate causes were associated with labor and operating problems, shortage of cement railcars, severe weather, tie-in of coal-burning and pollution-control facilities, production curtailments to meet environmental regulations, and an unusual timing of residential and nonresidential construction cycles. However, a deeper cause may be the inability of the industry to raise capital for expansion. Returns on investment averaging less than 8% during the past 15 years and the cyclical nature of cement demand are primary obstacles to expansion. Although shipments in 1979 were aproximately the same as in 1978, no shortages were reported for 1979.

PRICES

The average mill value[19] of all types of portland cement during 1978-79 was $40.70 ($46.24) per ton, $4.34 ($9.88) per ton higher than in 1977. The values ranged from a low of $29.18 ($33.85) in New York and Maine to a high of $58.10 ($62.57) in Hawaii. Increased energy and labor costs were a major cause of price increases for cement.

According to Engineering News-Record, cement prices compiled by their field reporters from monthly market quotations for 20 U.S. cities ranged from $44.79 to $49.10 f.o.b. in 1978, and from $50.00 to $55.70 in 1979.

An open issue since late 1976 and throughout 1979 were the class action suits filed by the States of Alabama, Arizona, California, Colorado, Florida, Kansas, Louisiana, Minnesota, Missouri, Montana, Nebraska, New Mexico, Oregon, Texas, Utah, and numerous private parties. The lawsuits allege violations of State and/or Federal antitrust laws. The specific charges include: Price fixing in competition; increased prices; establishment of a system of pricing linking mill prices, delivered prices, freight allowances, and credit terms; and the allocation of customs and territories.

The U.S. International Trade Commission (ITC) ruled in late 1978 that imports of portland cement from Canada were not injuring the cement industry in the United States. This investigation, began in late 1977, asked that the U.S. Department of the

Treasury determine if sales of cement from Canada were made at less than fair value. A critical factor was that cement was extremely short in Western and Midwestern States and that many Congressmen had interceded on behalf of a desperate construction industry who wanted cement at any price, from any source. By the end of 1978, the judgement had a petition filed against it by an American manufacturer asking that antidumping duties be assessed with regard to cement imports from Canada.

Table 16.—Average mill value in bulk, of cement in the United States[1]

(Per short ton)

Year	Portland cement	Prepared masonry cement[2]	All classes of cement
1975 ------	$31.09	$38.90	$31.41
1976 ------	33.86	42.63	34.25
1977 ------	36.36	45.08	36.76
1978 ------	40.70	50.53	41.17
1979 ------	46.24	54.59	46.61

[1] Includes Puerto Rico.

[2] Masonry cement made at cement plants only.

FOREIGN TRADE

Exported cement was equivalent to 0.1% (0.2%) of domestic shipments by quantity. In 1978, three countries—Canada, Mexico, and the Bahamas received nearly 80% (95%) of the 57,817 (150,846) tons of cement valued at $8.9 ($14.6) million which was exported to a total of more than 37 (31) countries.

Hydraulic cement and clinker imported into the United States totaled 6.6 (9.4) million tons increasing 64% (133%) in quantity and 103% (244%) in value over that of 1977. The 1979 imports exceeded the previous record year of 1973 when 6.7 million tons were imported. Imported cement and clinker equaled 7.8% (11.3%) of domestic shipments by weight and 6.6% (9.1%) by value.

Effective January 1, 1980, the import duty for nations with most favored trade status remained at 1 cent per 100 pounds for white nonstaining portland cement and free for other hydraulic cement and clinker.

Canada continued to supply the largest amount of imported cement and clinker. In 1978, Canada provided 46% of the total, followed by Japan, 16%; Mexico, 12%; Spain, 7%; and France, 5%. In 1979, the countries providing the largest amounts of imported cement were Canada, 47%; Japan, 16%; the United Kingdom, 8%; Spain, 6%; and Mexico, 6%.

In 1978-79, the U.S. net import reliance as a percentage of apparent consumption was 7% and 11%, respectively.

Clinker comprised 45% (50%) of the total imports, compared with 40% in 1977, 31% in 1976, 33% in 1975, 32% in 1974, and 41% in 1973.

Table 17.—U.S. exports of hydraulic cement, by country

Country	1977		1978[1]		1979	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Austria	143	$44	--	--	--	--
Australia	161	50	127	$58	49	$17
Bahamas	12,514	641	2,155	113	15,904	351
Belgium-Luxembourg	105	31	32	11	37	16
Belize	255	16	4	2	--	--
Bermuda	201	36	3	5	--	--
Brazil	72	49	45	11	--	--
Canada	156,047	13,156	35,207	4,400	88,965	8,034
Colombia	234	43	21	6	352	133
Chile	84	26	30	15	47	23
Dominican Republic	1,503	286	391	199	135	81
Ecuador	124	53	142	49	187	58
France	158	46	19	7	60	16
French West Indies	986	25	8	2	--	--
Germany, Federal Republic of	115	16	11	32	20	
Guatemala	2,748	221	367	91	159	34
Guyana	3,091	159	1	2	--	--
Haiti	1,445	94	8	1	5	4
Indonesia	183	69	--	--	35	1
Italy	485	141	17	23	248	104
Jamaica	188	113	11	5	--	--
Japan	848	493	326	127	157	71
Korea, Republic of	323	147	--	--	--	--
Kuwait	69	16	6	7	3	1
Leeward and Windward Islands	24,715	983	2,581	105	533	32
Libya	1,167	287	--	--	--	--
Mexico	10,407	2,011	8,985	2,301	38,785	4,334
Netherlands Antilles	838	87	26	6	1,252	100
Nicaragua	984	79	96	10	--	--
Nigeria	1,522	98	--	--	--	--
Other Pacific Islands, n.e.c.[2]	565	46	--	--	29	71
Panama	17	9	113	13	12	5
Peru	1,888	221	1,440	156	2	1
Philippines	230	68	254	103	54	30
Saudi Arabia	5,826	1,792	652	186	450	183
Singapore	94	36	147	65	13	7
South Africa, Republic of	395	62	2	4	--	--
Spain	140	69	24	18	12	8
Switzerland	278	104	160	77	45	27
Taiwan	68	21	189	58	2	2
Trinidad and Tobago	3,083	306	1,858	131	997	31
Turkey	234	94	--	--	--	--
Turks and Caicos Islands	556	34	--	--	--	--
United Kingdom	186	77	48	20	84	25
Venezuela	705	281	909	190	566	253
Yugoslavia	296	204	--	--	--	--
Other	2,453	797	1,397	362	1,634	449
Total[3]	238,906	23,740	57,817	8,950	150,846	14,572

[1] Hydraulic cement and hydraulic clinker; excludes hydraulic cement concrete mixes, which for years prior to 1978 were reported in official trade returns in a single category together with hydraulic cement and hydraulic cement clinker.

[2] Includes U.S. Trust Territory of the Pacific, previously listed separately.

[3] Data may not add to totals shown because of independent rounding.

Table 18.—U.S. imports for consumption of hydraulic cement and clinker, by country

(Thousand short tons and thousand dollars)

Country	1977		1978			1979		
	Quantity	Value	Quantity	Value		Quantity	Value	
		Customs		Customs	C.i.f.[1]		Customs	C.i.f.[1]
Bahamas	90	2,562	307	9,970	11,090	487	19,929	22,728
Belgium-Luxembourg	21	1,142	24	1,222	1,802	13	938	1,333
Canada	2,203	52,197	3,024	85,499	98,608	4,440	137,975	151,247
Colombia	5	170	(2)	--	92	34	1,250	1,535
France	196	5,452	317	9,324	10,518	405	14,425	16,052
Germany, Federal Republic of	(2)	35	37	772	1,110	(2)	48	55
Japan	362	5,332	1,038	28,791	36,207	1,523	52,605	57,822
Mexico	635	16,449	817	26,973	30,054	525	19,581	22,471
Norway	210	4,462	208	4,466	5,862	281	7,182	9,760
Spain	105	1,974	434	12,020	14,831	548	14,629	21,344
United Kingdom	186	3,968	302	8,782	11,258	759	26,249	31,636
Yugoslavia	3	243	3	219	357	2	184	247
Other	(2)	17	86	2,605	3,367	395	7,461	14,934
Total[3]	4,016	94,005	6,597	190,643	225,151	9,412	302,356	351,164

[1] C.i.f. Cost, insurance, and freight.
[2] Less than 1/2 unit.
[3] Data may not add to totals shown because of independent rounding.

Table 19.—U.S. imports for consumption of clinker, by country

(Thousand short tons and thousand dollars)

Country	1977			1978			1979		
		Value			Value			Value	
	Quantity	Custom	C.i.f.[1]	Quantity	Custom	C.i.f.[1]	Quantity	Custom	C.i.f.[1]
Australia	--	--	--	1	69	133	160	3,670	5,430
Bahamas	--	--	--	16	376	458	--	--	--
Canada	855	15,642	17,291	1,113	22,827	25,480	1,887	50,531	54,684
French West Indies	--	--	--	--	--	--	7	133	184
France	194	5,020	5,331	314	9,092	10,195	385	13,931	15,262
Germany, Federal Republic of	--	--	--	36	728	1,055	--	--	--
Japan	360	4,454	6,170	980	25,945	32,973	1,384	40,849	49,594
Korea, Republic of	--	--	--	31	313	441	--	--	--
Mexico	54	1,105	1,102	(2)	6	6	(2)	2	2
Peru	--	--	--	--	--	--	105	2,866	3,631
Spain	30	551	716	324	6,733	8,664	398	9,980	12,159
United Kingdom	120	2,452	2,869	153	3,175	4,348	341	9,911	11,721
Total	1,613	29,224	33,479	2,968	69,264	83,753	4,667	131,873	152,667

[1] C.i.f. cost, insurnace, and freight.
[2] Less than 1/2 unit.

Table 20.—U.S imports for consumption of hydraulic cement and clinker by customs districts and country

(Thousand short tons and thousand dollars)

Customs district and country	1977 Quantity	1977 Value Customs	1978 Quantity	1978 Value Customs	1978 Value C.i.f.[1]	1979 Quantity	1979 Value Customs	1979 Value C.i.f.[1]
Anchorage:								
Canada	51	2,014	18	973	1,162	20	1,014	1,045
Japan	r7	157	(2)	1	2	(2)	3	4
Total	r58	2,171	18	974	1,164	20	1,017	1,049
Boston: Canada	(2)	5	--	--	--	(2)	1	1
Buffalo:								
Canada	r580	13,112	664	16,101	22,697	765	19,840	23,639
Mexico	1	14	--	--	--	--	--	--
Total	r581	13,126	664	16,101	22,697	765	19,840	23,639
Charleston, S.C.:								
United Kingdom	--	--	(2)	(2)	(2)	--	--	--
Chicago:								
Belgium-Luxembourg	(2)	1	(2)	1	1	--	--	--
Canada	6	160	49	1,361	1,498	273	7,819	8,451
Netherlands	(2)	3	--	--	--	--	--	--
Spain	--	--	5	372	462	82	1,605	1,851
United Kingdom	(2)	1	--	--	--	--	--	--
Total	6	165	54	1,734	1,961	355	9,424	10,302
Cleveland:								
Canada	8	177	134	3,569	4,116	257	8,808	9,744
Germany, Federal Republic of	--	--	--	--	--	(2)	9	13
United Kingdom	--	--	--	--	--	(2)	3	6
Total	8	177	134	3,569	4,116	257	8,820	9,763
Detroit: Canada	655	13,158	828	22,647	24,360	1,186	32,845	34,946
Duluth:								
Canada	--	--	87	2,788	3,379	194	6,247	7,095
France	--	--	--	--	--	20	481	769
United Kingdom	--	--	--	--	--	20	485	775
Total	--	--	87	2,788	3,379	234	7,213	8,639
El Paso:								
Brazil	--	--	(2)	(2)	1	--	--	--
Canada	--	--	--	--	--	(2)	7	8
Mexico	92	2,569	58	2,966	2,966	39	2,188	2,189
Sweden	--	--	--	--	--	(2)	1	1
Total	92	2,569	58	2,966	2,967	39	2,196	2,198
Galveston:								
Canada	--	--	59	1,075	1,477	--	--	--
France	--	--	28	847	1,027	--	--	--
Mexico	5	129	114	3,596	4,257	44	1,396	1,712
Peru	--	--	--	--	--	79	2,273	2,762
Spain	30	551	169	3,364	4,258	69	1,935	2,314
United Kingdom	28	525	--	--	--	--	--	--
Total	63	1,205	370	8,882	11,019	192	5,604	6,788
Great Falls: Canada	6	305	53	1,421	1,601	10	620	738
Houston:								
Germany, Federal Republic of	(2)	10	--	--	--	--	--	--
Mexico	33	755	100	2,569	3,029	54	1,464	1,732
Spain	--	--	64	1,536	1,802	28	847	953
United Kingdom	r66	1,365	79	1,449	2,204	321	9,462	10,991
Total	99	2,130	243	5,554	7,035	403	11,773	13,676
Laredo:								
Canada	--	--	(2)	4	4	2	79	79
Mexico	100	3,384	138	5,390	5,390	94	4,463	4,458
Total	100	3,384	138	5,394	5,394	96	4,542	4,538

See footnotes at end of table.

Table 20.—U.S imports for consumption of hydraulic cement and clinker by customs districts and country —Continued

(Thousand short tons and thousand dollars)

Customs district and country	1977		1978			1979		
	Quantity	Value Customs	Quantity	Value		Quantity	Value	
				Customs	C.i.f.[1]		Customs	C.i.f.[1]
Los Angeles:								
Australia	--	--	3	138	264	52	1,356	2,145
Canada	--	--	161	4,542	5,082	383	12,791	13,791
France	--	--	37	857	1,291	36	788	1,196
Germany, Federal Republic of	(2)	10	(2)	29	35	(2)	38	42
Japan	--	--	1	195	200	501	15,121	17,628
Peru	--	--	8	269	392	26	991	1,004
Spain	1	85	3	140	261	1	140	255
Yugoslavia	(2)	55	1	86	148	1	87	169
Total	1	150	214	6,256	7,673	1,000	31,312	36,232
Miami:								
Bahamas	63	1,753	127	4,113	4,434	303	12,393	13,706
Belgium-Luxembourg	6	335	3	310	394	5	372	484
Colombia	--	--	--	--	--	31	1,013	1,242
Denmark	--	--	21	686	766	--	--	--
Mexico	130	2,644	103	2,799	3,610	79	3,480	4,055
Norway	--	--	--	--	--	45	1,041	1,457
Spain	23	284	27	792	930	65	1,841	2,674
Total	222	5,016	281	8,700	10,134	528	20,140	23,618
Milwaukee:								
Canada	(2)	2	37	1,018	1,166	119	3,853	4,408
United Kingdom	--	--	--	--	--	(2)	2	4
Total	(2)	2	37	1,018	1,166	119	3,855	4,412
New Orleans:								
Bahamas	--	--	71	2,281	2,771	93	3,868	4,900
Canada	(2)	6	--	--	--	--	--	--
Germany, Federal Republic of	--	--	1	12	15	--	--	--
Greece	--	--	21	1,104	1,472	11	286	410
Mexico	73	1,680	90	2,507	2,888	61	1,829	2,086
Peru	--	--	--	--	--	26	594	869
Spain	--	--	--	--	--	118	3,382	4,419
United Kingdom	21	495	194	5,678	8,157	241	6,745	9,141
Total	94	2,181	377	11,582	15,303	550	16,704	21,825
New York City:								
Germany, Federal Republic of	--	--	(2)	(2)	(2)	--	--	--
Norway	208	3,925	205	3,891	5,137	185	4,779	6,489
Sweden	--	--	--	--	--	24	569	714
Total	208	3,925	205	3,891	5,137	209	5,348	7,203
Nogales: Mexico	1	40	12	336	336	2	139	139
Norfolk:								
France	36	2,231	38	2,383	2,566	58	4,735	5,032
Mexico	30	572	--	--	--	--	--	--
United Kingdom	--	--	(2)	5	9	--	--	--
Total	66	2,803	38	2,388	2,575	58	4,735	5,032
Ogdensburg: Canada	151	3,774	77	1,644	1,954	79	1,991	2,186
Pembina: Canada	116	4,132	247	9,949	10,666	228	9,720	10,778
Philadelphia:								
Canada	--	--	--	--	--	(2)	3	2
Germany, Federal Republic of	(2)	5	(2)	3	4	--	--	--
Yugoslavia	3	188	2	133	209	1	41	67
Total	3	193	2	136	213	1	44	69
Port Arthur:								
France	--	--	10	171	235	--	--	--
Germany, Federal Republic of	--	--	36	728	1,055	--	--	--
Mexico	21	299	28	442	788	40	752	1,343
Spain	--	--	86	1,461	2,142	97	2,398	2,935
Total	21	299	160	2,802	4,220	137	3,150	4,278

See footnotes at end of table.

Table 20.—U.S imports for consumption of hydraulic cement and clinker by customs districts and country —Continued

(Thousand short tons and thousand dollars)

Customs district and country	1977		1978			1979		
	Quantity	Value Customs	Quantity	Value Customs	Value C.i.f.[1]	Quantity	Value Customs	Value C.i.f.[1]
Portland, Maine:								
Canada	34	1,041	32	872	887	22	630	630
United Kingdom	--	--	(3)	1	1	--	--	--
Total	34	1,041	32	873	888	22	630	630
Portland, Oreg.:								
Canada	--	--	3	128	139	27	1,014	1,102
Japan	--	--	68	1,857	2,064	131	4,043	5,392
Mexico	--	--	--	--	--	15	308	339
Total	--	--	71	1,985	2,203	173	5,365	6,833
Providence: Canada	1	38	--	--	--	--	--	--
St. Albans:								
Canada	289	7,730	220	5,699	5,301	205	5,795	4,898
Germany, Federal Republic of	(3)	(3)	--	--	--	--	--	--
South Africa, Republic of	--	--	--	--	--	(3)	5	6
Total	289	7,730	220	5,699	5,301	205	5,800	4,904
San Diego:								
Canada	--	--	(3)	2	2	--	--	--
Japan	--	--	106	3,404	4,441	33	882	1,011
Mexico	19	1,008	34	1,918	1,931	14	831	831
Panama	--	--	--	--	--	24	1,087	1,492
Peru	--	--	--	--	--	8	275	421
United Kingdom	--	--	--	--	--	55	3,789	4,741
Total	19	1,008	140	5,324	6,374	134	6,864	8,496
San Francisco:								
Australia	--	--	--	--	--	117	2,719	4,050
Bermuda	--	--	(3)	(3)	1	--	--	--
Canada	--	--	(3)	2	3	150	6,151	7,548
Japan	--	--	304	8,810	11,551	318	9,413	12,462
Korea, Republic of	--	--	31	313	441	--	--	--
Mexico	--	--	--	--	--	23	716	1,130
Total	--	--	335	9,125	11,996	608	18,999	25,190
San Juan:								
Belgium-Luxembourg	15	800	18	746	1,194	7	470	733
Colombia	5	170	1	75	92	4	237	293
Denmark	(3)	4	--	--	--	--	--	--
Dominican Republic	(3)	5	1	15	28	(3)	2	4
France	(3)	11	(3)	13	22	(3)	4	7
Italy	--	--	(3)	3	3	(3)	3	6
Japan	--	--	--	--	--	(3)	3	4
Spain	7	500	8	606	1,051	9	772	1,428
Total	27	1,490	28	1,458	2,390	20	1,491	2,475
Seattle:								
Canada	305	6,547	322	9,690	10,402	358	13,345	14,466
Japan	r356	5,175	559	14,524	16,949	539	17,925	21,320
Mexico	(3)	6	--	--	--	19	658	709
United Kingdom	--	--	--	--	--	(3)	5	11
Total	r661	11,728	881	24,214	27,351	916	31,933	36,506
Tampa:								
Bahamas	27	809	109	3,576	4,286	90	3,668	4,122
Belgium-Luxembourg	(3)	7	2	166	212	1	96	116
Canada	--	--	33	2,013	2,542	162	5,404	5,690
France	160	3,210	205	5,054	5,377	292	8,417	9,047
French West Indies	--	--	--	--	--	7	133	184
Germany, Federal Republic of	(3)	9	--	--	--	--	--	--
Mexico	130	3,348	141	4,451	4,858	42	1,307	1,748
Norway	r3	538	3	575	725	51	1,363	1,814
Spain	43	554	72	3,749	3,925	73	3,075	4,316

See footnotes at end of table.

Table 20.—U.S imports for consumption of hydraulic cement and clinker by customs districts and country —Continued

(Thousand short tons and thousand dollars)

Customs district and country	1977		1978			1979		
	Quantity	Value Customs	Quantity	Value Customs	Value C.i.f.[1]	Quantity	Value Customs	Value C.i.f.[1]
Tampa: —Continued								
Sweden	--	--	--	--	--	22	856	856
United Kingdom	71	1,583	28	1,648	1,653	122	5,759	5,967
Total	434	10,058	593	21,232	23,578	862	30,078	33,860
Savannah:								
Denmark	--	--	--	--	--	(2)	7	9
Spain	--	--	--	--	--	4	149	198
Total	--	--	--	--	--	4	156	207
Baltimore:								
New Zealand	--	--	--	--	--	(2)	2	4
Yugoslavia	--	--	--	--	--	(2)	7	11
Total	--	--	--	--	--	(2)	9	15
Grand total[3]	r4,016	r94,003	6,597	190,642	225,151	9,413	302,359	351,164

[r] Revised.
[1] Value = C.i.f. (cost, insurance, freight).
[2] Less than 1/2 unit.
[3] Data may not add to totals shown because of independent rounding.

WORLD REVIEW

The trend continued worldwide in plant modernizations to reduce energy consumption; this included conversion to dry-process preheater, precalciner kilns. Topics of concern around the world included supply shortages and pricing controversies. In 1979, Cembureau held in Cannes, France, a special seminar on the subject of how to deal with inflation.

Hungary, Algeria, Egypt, Morocco, Tunisia, and Saudi Arabia are reportedly striving to achieve self-sufficiency in cement supply.

Greece, Turkey, Poland, Kenya, Jordan, Korea, Taiwan, Colombia, Costa Rica, and Mexico are reportedly striving to achieve increased export tonnages.

During 1978-79, world cement production increased to 938 (958) million tons, 7% (10%) more than the 1977 total of 873 million tons. The largest increase in production was in mainland China where overall production was 12.7 (22.2) million tons greater than the 59.2 million tons of 1977. On a percentage basis, Tunisia showed the greatest (54%) increase in 1978, and Algeria showed the greatest (104%) increase in 1979, compared with 1977 production.

Afghanistan.—The present uncertain state of affairs makes it difficult to update progress on cement plant programs. Previously, the Asian Development Bank, Manila, Philippines, had commissioned a mission of experts to examine all aspects of the Afghan cement industry. In the Kandahar region a new 1,760-short-ton-per-day plant was scheduled for completion in 1979.

Algeria.—Algeria's Societe Nationale des Materiaux Construction (SNMC), the nation's public construction corporation, continued to launch programs for expanding cement capacity. Plans were to boost current output to 3 million tons with operations then being built. Additional projects were underway for another 9.5 million tons so the country could reach the production level of up to 12.5 million tons capacity in 1980.

Four new plants were scheduled to go onstream in 1978-79: Ain el Kebira, 1.1 million short tons per year; Saida, 550,000 short tons per year; Beni-Saf, 1.1-million-short-ton-per-year; and El Asnam, a 1.1-million-short-tons per-year plant. In 1980, three plants are expected to be completed, one each at Bouira (1.1 million short tons per year), Batna (550,000 short tons per year), and Djelta (550,000 short tons per year).

Argentina.—Three modernization and expansion programs undertaken by Corporacon Cementera Argentina S.A. (Corecemar) would increase company capacity by 850,000 tons. At Yocsina, two projects included the equipping of one kiln with a four-stage cyclone preheater and the extension of the raw mill, both projects to be completed by yearend 1979. The other project was at the Mendoza plant, which was to receive a new 2,200-short-ton-per-day, four-stage cyclone-preheater-and-grate cooler system. This project was to be completed in early 1980.

Two other Argentine projects included one for Juan Minetti S.A. at a Cordoba site where a new 600,000-short-ton-per-year plant was to be built and one by Loma Negra Compania Industrial Argentia S.A. at Olivaria which is an expansion and modification of an existing long dry-kiln system to a two-stage preheater unit to result in a capacity increase of 440 short tons per day.

Australia.—Blue Circle Southern Cement, Ltd., commissioned its 825,000-short-ton-per-year expansion program at its Berrima plant in New South Wales. The expansion was to include a four-stage cyclone preheater and a planetary cooler. Blue Circle Southern Cement was formed in 1974 from a merger of interests of the Associated Portland Cement Manufacturers of the United Kingdom and Broken Hill Proprietary Ltd. Each held 42% of the equity.

Austria.—Peggauer Zementwerke at Peggan placed an order for an 800-short-ton-per-day kiln in 1978. This plant was a single-kiln, gas-fired operation with a capacity of 165,000 short tons per year.

Bahamas.—United States Steel Corp., Pittsburgh, Pa., sold its 940,000-short-ton-per-year plant at Grand Bahamas to the International Development Corp. S.A. (IDC), New York. IDC is a holding company with worldwide interests including companies engaged in production and international marketing of cement.

Barbados.—Barbados and Guyana agreed to build a cement plant in Barbados. The plant was to be operational in 1980 and would produce 250,000 short tons per year of clinker, of which Barbados would grind 150,000 tons and the remaining 100,000 tons would be shipped to Guyana for grinding.

Belgium.—The Belgian Cement Association completed a study to determine optimum conditions for using coal in rotary kilns. The report states that coal shale or slurries may be used as kiln feeds either by insufflation through the burner pipe or by mixing them with the kiln feed. Precautions must be taken against the premature formation of melt by sufficient momentum in the burner pipe, and against an excess of free lime in the clinker by selecting an improper kind of shale.[30]

Bolivia.—Expansion of Bolivia's cement industry was reportedly necessary to meet expected growth in demand and so that national development plans could be implemented. This included substantial investments in highways, irrigation, and airports. New plants included an $88 million complex to be built in Yacuces. The dry-process plant would have an annual clinker production capacity of 335,000 tons and the kiln would be equipped with a cyclone preheater. Startup was scheduled by 1981.

Brazil.—The Brazilian Portland Cement Association reported that production doubled during the period 1971-76 to 19.1 million short tons per year. By 1983, industry output was projected to be 38 million short tons per year.

In 1978, Lone Star Industries and Lafarge S.A. agreed to combine all of their Brazilian cement operations. Lafarge's 60% interest in Companhia Mineria de Cimento Portland, Cimento Portland Pains, and Ciment-invest Ltd., were exchanged for a 54% interest in Lone Star's wholly owned Companhia Nacional de Cimento Portland, with Lone Star retaining 46% in the expanded venture. Lone Star and Lafarge signed an agreement to build a new 770,000-short-ton-per-year plant at Cantalgo, State of Rio de Janiero.

Itabira Agro-Industrial S.A. planned to add a 1,400-short-ton-per-day kiln at its Capaco Bonita plant in the State of Sao Paulo.

Bulgaria.—The most recent plant expansion, at Beli Izvor, was part of Bulgaria's VII Plan (1976-80) in which national cement production was scheduled to reach about 10 million short tons per year of output.

Canada.—Inland Cement Industries Ltd. (subsidiary of Genstar Ltd.), started up its new 1.1-million-short-ton-per-year plant on Tilbury Island near Vancouver, British Columbia. Major equipment included a 3,540-short-ton-per-day kiln, a four-stage preheater, and a planetary cooler. The company was also expanding its Edmonton, Alberta, plant to 1.5 million short tons per year with startup scheduled for 1980. Also included was the conversion from gas to coal. Coal was to be mined underground, north of the plant.

Canada Cement Lafarge Ltd. placed onstream in 1978 a 500,000-short-ton-per-year expansion project at its Brookfield, Nova Scotia plant. During 1978, the company was expanding its Exshaw, Alberta, plant by installation of a suspension preheater with precalciner, rotary kiln, and clinker cooler. Completion was scheduled for 1980.

Ciment Quebec, Inc., began expansion of its St. Basile de Portneuf, Quebec plant with startup scheduled for 1981.

St. Mary's Cement Co. brought onstream its expanded production facility at St. Mary's, Ontario. The 2,000-short-ton-per-day system requires 3.4 million Btu's to produce 1 ton of clinker.[21]

China: *Mainland.*—The national cement industry topped the 1978 target of 54 million tons 49 days ahead of time with a 20% increase in annual production over 1977. Twenty of the 49 large and medium-sized plants surpassed annual production timetables.[22]

In 1978, China resumed importing of cement from Japan, marking the first time in 22 years for such a transaction. China agreed to purchase 2 million tons of Japanese cement in 1979. Ten Japanese cement companies were involved.

Taiwan.-New production facilities and additions will boost cement output from 11.5 million tons to more than 16 million tons by 1986. One new plant started up in 1978 with a capacity of 800,000 short tons per year. There are more than 20 cement plants in Taiwan and 98% of them are on the western side of the island.

Colombia.—Acerias Paz del Rio was constructing a 600,000-short-ton-per-year slag cement plant at Belencito. Completion was scheduled for 1980. Samper S.A. Bogota awarded a contract for the extension of its Municipiet La Calera plant. The 1,500-short-ton-per-day production line was to include a two-stage preheater, a rotary kiln, and a planetary clinker cooler.

Costa Rica.—Corporacion Costarricense de Desarrollo was building a new 1,430-short-ton-per-day, dry-process cement plant in Guanacasta Province.

Cuba.—In 1978, although cement was in short supply, Cuba exported it to obtain hard currency.[23]

Cement exports to Honduras and other Carribean countries amounted to 250,000 tons in 1978. Cuba expected to build additional cement plants and expand exports during the 5-year-plan period ending in 1986.[24]

Cuba's largest cement manufacturing plant was being built at Cienfuegos. It was to have a capacity of 1.8 million short tons per year.

Czechoslovakia.—The country's VI Plan (1976-80) projected that its cement production would reach approximately 13 million tons. Imports were necessary throughout the 1970's and its principal sources were the U.S.S.R., Romania, and the German Democratic Republic.

Dominican Republic.—In February 1978, Cementos Cibao C. por A. began partial operations with a first kiln.

Ecuador.—Empresa Cementos Selvalegre S.A. was building a 380,000-ton plant at Otavalo. Empresa Industrias Guapan S.A. currently was building a new 400,000-ton plant at Ayogues. Both plants were scheduled to be operational by 1980.

Egypt.—Further expansion programs undertaken by the Egyptian cement industry during 1978-79 were aimed at reducing dependence upon imports and ensuring that industrialization programs were not hampered.

The Suez Cement Co. was building the first privately owned cement plant since nationalization of the industry in 1960. The 1.1-million-short-ton-per-year plant was to be operational in early 1981. Because the location is near the sea and raw materials are high in chlorides, it was essential that a bypass system be used to control the alkali content.

Helwan Portland Cement Co. planned to convert its two existing wet-process production lines to dry process by 1981. Both would be equipped with four-stage preheaters and precalcining systems and would have a combined capacity of 3.3 million short tons per year.

El Salvador.—Cemento de El Salvador S.A. at its El Ronco location expanded the dry-process system by 1,100 short tons per day by adding a four-stage preheater, a rotary kiln, and a planetary cooler.

France.—The French Government announced in 1978 it's lifting of all existing controls on industrial pricing. The move was expected to help resolve economic problems that French cement producers had been experiencing.

Gabon.—Two new cement plants were scheduled for Societe des Ciments du Gabon, a 1,100-short-ton-per-day wet-process plant at N'toum and a 110,000-short-ton-per-year clinker grinding plant at Franceville. Both were scheduled to go onstream in 1979.

Germany, Federal Republic of.—Hoesch Huttenwerke AG developed a new process for granulation of blast furnace slag, a widely used pozzolanic material in cement in Germany.[25]

Greece.—Among European cement exporters, Greece ranked second in 1978-79. Its principal export market area was the Middle East (80% of sales). Industry representatives claimed that the low domestic cement prices imposed by the Government since May 1977 coupled with increased production costs (electricity, wages, fuel) were negative factors for planning new units. Four companies shared the country's production capacity which in 1978 was 11.9 million tons.[26]

Projections of the Greek industry's production capacity indicated 16 million tons by 1980 and 19 million tons by 1984. The margin available for export was expected to grow to 6.6 million tons by 1980 with an increasing home market demand narrowing this figure to some 4.3 million tons by 1983.

Titan Cement Co. had doubled the capacity of its Kamari facility, the Halyps Cement Co. had expanded it Aspropyrgos plant by 1,650 short tons per day, and Heracles General planned a new 1.7-million-short-ton-per-year plant in the Mylaski region.

Guatemala.—Cementos Novella S.A. was expanding its No. 2 plant at San Miguel, which produced 1,000 short tons per day with a four-stage preheater kiln. Forty percent of the clinker was to be sent to its older La Pedrera plant in Guatemala City which had surplus grinding capacity. The new production line was scheduled to go onsteam in 1979.[27]

Guinea.—The Republic of Guinea awarded a contract for the construction of a clinker grinding plant at Conakry. The operation was to have a 275,000-short-ton-per-year capacity, with startup scheduled by the end of 1979.

Honduras.—Industria Cementera Hondurena S.A. awarded a contract to build a new 1,980-short-ton-per-day plant at Piedras Azules. The operation was to go onstream by mid-1981. Output was to be 1,320 short tons per day of clinker mixed with 660 short tons per day of pozzolan.

India.—During 1978-79, the Associated Cement Companies (ACC), the largest cement firm in the country, undertook a major investment program to add 2 million tons additional capacity over the next 3 years by expanding three existing plants and building a new operation in the Himalayan foothills. This expansion was made possible recently by the Government's allowing of 12% post-tax returns on net worth and relaxation of restrictions on "large" businesses. There had been little investment made in new cement plants over the previous several years, with the Government admitting that it had fixed prices for cement too low.

Indonesia.—P. T. Semen Gresik fired up its kiln at the Gresik Persero factory in 1978, marking its third expansion and bringing plant capacity up to 1.65 million short tons per year and making Indonesia self-sufficient. In 1978, the country imported 300,000 tons of cement. Annual consumption was about 4.5 million tons.[28]

Iran.—Aria Cement Corp.'s new facility at Isfahan was scheduled to go onstream in 1978. The two-kiln operation is rated at 3,600 short tons per day clinker capacity. Granulated blast furnace slag from a neighboring iron works was to be utilized. Other projects included a new 3,200-short-ton-per-day plant at Behbahan, a new 2,400-short-ton-per-day plant at Kermanshah, and a new 2,200-short-ton-per-day plant at Neka.

Iraq.—Iraq's cement industry goal was reportedly aimed at achieving an 11-million-metric-ton capacity by 1980. Several plant programs were underway. The Badoosh Cement plant in northern Iraq placed its 1,650-short-ton-per-day expansion onstream. Iraq Cement Public Co. put onstream a 2.5-million-ton-plant at Kufa.

Jamaica.—The Government of Jamaica agreed with Venezuela to jointly explore the possibility of constructing a second cement plant on the island. The proposed 660,000-short-ton-per-day plant was to be financed 70% by Jamaica and 30% by Venezuela through a private organization.

Japan.—The Cement Association of Japan reported that in 1978 both production and shipments reached alltime highs. Production was at 93.5 million tons in 1978, up 16% over 1977. Domestic shipments rose 14% to 87.3 million tons. Exports jumped 30% to reach 9.1 million tons, a new record. However, in a marked turnabout, Japan cement industry fell from unprecedented large profit levels in 1978 to substantial profit reduction in 1979. Fuel oil shortages and rapidly escalated cost are causing the closing of plants and substantial cement price increases.

The Japan Economic Journal viewed the sale of Onoda Cement's reinfored suspension preheaters to three American cement firms (Kaiser, Marquette, and Ideal) as a great breakthrough for further U.S. sales of pyroprocessing equipment.

Nihon Cement Co. Ltd. and the Bridgeport Tire Co. jointly developed a new technology for development of used rubber tires as fuel and raw material for cement production. The process was put into practice in 1978. Between 45,000 and 50,000 used tires (300 tons) a month were to be utilized.

Korea, North.—By the conclusion of the 6-year plan in 1982, output was projected to reach 20 million tons. As part of this expansion, cement plants with an aggregate capacity of 10 million tons were to be built in the Suchon and Chonnae areas.

Korea, Republic of.—Cement plant expansion programs currently underway in Korea were scheduled to raise national capacity to over 21 million tons by 1980. Notably, the Ssang Yong Cement Industrial Co., Ltd., plant at Yong-Wol was adding 2.2 million tons, its Mukyong plant was being expanded to 400,000 tons, and its Dong Hae plant was adding 3.4 million tons. Dong Hae, when completed would have a capacity of 8.8 million tons. All of Dong Hae's production was to be exported.[29]

Libya.—At Hawari, a new two-kiln, 1.1-million-short-ton-per-year operation was placed onstream and inaugurated in September 1978.

Malaysia.—The Malaysian Government approved a $70 million expansion program of the Rawang cement plant in Selangor, Malaysia, operated by Associated Pan Malaysia Cement. The new plant to be built would have a capacity of 1.2 short tons per year by 1980.

Mexico.—Government forecasts noted that Mexican cement production was scheduled to increase to 25 million tons by 1982. Exports to the United States continued to be regarded as an important factor in realizing high-capacity utilization.

Blue Circle Ltd.'s associate company in Mexico, Empresas Tolteca de Mexico S.A., in December 1978 completed financial arrangements for the largest expansion of the country's cement industry in 5 years. Work began on a major project to increase the company's capacity by 2.4 million tons from its present 8.7-million-short-ton-per-year level. The program included construction of a 1.1-million-short-ton-per-year plant at Hermosillo in northwest Mexico, the modernization and expansion of six of Toltec's eight other existing plants, and improvement in ready-mix concrete facilities.

Morocco.—The Moroccan cement industry began several new plant programs. A new facility was being built for Asment de Temara S.A. near Rabat. This plant was scheduled to go onstream in 1979 with a capacity of 550,000 short tons per year. Scheduled to go onstream in 1978 was a new 1.1-million-short-ton-per-year plant at Quja.

Netherlands.—Alcoa Chemic Netherland BV, was to build a new plant to produce calcium aluminate cement and get it onstream in early 1980.[30] With this addition, Alcoa Chemic would be able to offer a full range of high alumina materials to the refractories, chemicals, and ceramics industries from a single European production source. The primary uses for calcium aluminate (CA-25) cement are in refractory mortars, castables, and in gunning mixes.

Nigeria.—Two new cement plants were reported onstream; namely, Ashaka Cement Co,'s plant in Bauchi State, rated at 880,000 short tons per year; and West African Portland Cement Co.'s plant at Shagamu, near Lagos.

Pakistan.—By the end of 1978, Pakistan was expected to be meeting all its cement needs, with some excess capacity available for export. A major reason for the previous short supply was stated to be inadequacies in distribution. A newly inaugurated revision of the supply system was to eliminate those difficulties. The country had been receiving imports from India and Romania; however, expansion at three existing plants, and the impending completion of four new units, were expected to eliminate shortages entirely.

Panama.—A 1,100-short-ton-per-day plant at Calyada Larga, owned by Empresa Estatal de Cemento "Bayano" north of Panama City, started production in 1978.

Peru.—A new precalciner unit at Pacasmayo started up in May 1978. The plant uses the indentical open-circuit grinding system for raw as well as finish grinding.[31]

The Philippines Cement Corp. awarded a contract to undertake a technical study of each of the 18 cement plants in the Philippines for the purpose of rating present capacity, determining steps to restore capacity where necessary, and reporting on antipollution control installations.[32]

Poland.—Poland became cement self-sufficient 4 years ago and from that point onward has been a net exporter of production. Cement output increased more than 50% during its last 5-year plan. Production under VII Plan (1976-80) is scheduled to again increase by more than 50% to 29 million tons by the end of 1980.

Saudi Arabia.—The nation's 5-year development plan calls for an increase in domestic production to 10 million short tons per year through a series of expansions. Completed in 1978 was a 1,600-short-ton-per-day expansion by the Yamama Saudi Cement Co., Ltd., at its Riyadh plant. Scheduled for completion by 1980 were El Kassein Cement Co.'s 2,200-short-ton-per-day plant at Buraydah and Yanbu Cement Co., Ltd.'s, 3,300-short-ton-per-day plant at Ras Baridi. Scheduled to be onstream in 1981 are Saudi Bahrain Cement Co.'s 1,600-short-ton-per-day plant at Abgeig and Southern Provence Cement Co.'s 5,500-short-ton-per-day plant at Gizan. Plant startup in 1982 is planned for the Saudi Kuwaiti Cement Manufacturing Co.'s new 7,700-short-ton-per-day plant on the Arabian Gulf coast.

South Africa, Republic of.—South Africa's cement export program was reportedly hit by the loss of its important Iranian market. South Africa's cement exports had previously reached record high levels. Middle East and Indian Ocean countries had been the chief markets. About one-eighth of industry production capacity had been exported. Generous government rebates on rail traffic had helped boost exports since most of the cement plants are located far from the main seaports.

A complaint of South African cement producers, reported in 1979, was that the current price for cement does not yield sufficient returns to reward shareholders properly and ensure the continued healthy development of the industry.[33]

Spain.—Spain is the world's foremost exporter of cement. The industry operates 54 production facilities throughout the country.[34]

Sweden.—Cementa AB added a 5,200-short-ton-per-day kiln line system at its Slite plant on the Island of Gotland. After startup, the Slite operation was to account for approximately 60% of Sweden's total cement capacity. The single kiln line is the largest in Europe.

Thailand.—Siam City Cement Co., Ltd., has undertaken an expansion program that will aproximately triple the capacity of the company's plant at Saraburi in central Thailand, making it the second largest cement producer in the country. The project also included construction of a large bulk distribution terminal.

Kaiser Cement & Gypsum Co. sold its 25% interest in Jalaprathan Cement Co. of Bangkok to the Thai firm's directors for $8 million. Kaiser will remain in management under an ongoing contract.[35]

Turkey.—By 1980, capacity of the Turkish cement industry was expected to stand at approximately 22 million short tons per year. National consumption at that time was projected to reach 18 million short tons per year. The remainder was to be available for export, mostly as clinker.

United Arab Emirates.—The National Cement Co., Ltd. put onstream in 1978 its new plant at Dubai. The annual capacity of this plant was 1,600 short tons per day. Scheduled for startup in 1980 was the Union Cement Co., Ltd.'s, plant expansion at Ras Al Khaima. The new kiln would add 1,600 short tons per day to existing capacity. In 1981, Al-Ain Cement Factory at Al-Ain was to start its new 2,000-short-ton-per-day plant.

United Kingdom.—In June 1978, the Associated Portland Cement Manufacturers Ltd., changed its name and since then has been trading worldwide as Blue Circle Industries Ltd. Different names used to distinguish various operations within the company are Blue Circle Overseas, Blue Circle Technical, Blue Circle Enterprises, and Blue Circle Cement. Each name represents an operation group of Blue Circle Industries, not a subsidiary company.

Yugoslavia.—Dalmacija Cement was expanding its plant at Paitizan with a 3,500-short-ton-per-day, dry-process kiln. The operation was reported to be one of the most modern in Europe and would make Yugoslavia self-sufficient in cement production. The favorable coastal location of the plant was to assist both internal raw material supply and exports to the Middle East.

Table 21.—Hydraulic cement: World production, by country

(Thousand short tons)

Country	1976	1977	1978[p]	1979[e]
North America:				
Bahamas	299	25	407	400
Canada	10,609	10,588	11,638	[1]13,046
Costa Rica	399	447	468	600
Cuba	2,757	2,929	2,989	2,900
Dominican Republic	[r]721	948	[1]955	1,000
El Salvador	356	408	573	600
Guatemala	[r]490	541	568	[1]632
Haiti	253	293	274	300
Honduras	245	416	287	300
Jamaica	403	367	324	400
Mexico	13,871	14,580	15,494	16,600
Nicaragua	230	251	177	200
Panama	[r]311	299	292	300
Trinidad and Tobago	[r]266	238	243	[1]238
United States (including Puerto Rico)	74,495	80,058	85,480	[1]85,904
South America:				
Argentina	6,296	6,425	6,783	7,000
Bolivia	243	292	279	300
Brazil	[r]21,105	21,123	24,361	26,800
Chile	[r]1,067	1,256	1,297	[1]1,498
Colombia	3,982	3,635	4,577	4,740
Ecuador	679	690	1,102	1,100
Paraguay	171	220	183	200
Peru	2,167	2,172	2,226	[1]2,227
Surinam	[e]55	53	66	60
Uruguay	745	752	743	750
Venezuela	3,900	3,457	3,777	4,500
Europe:				
Albania	772	827	992	1,100
Austria	6,482	6,606	6,322	[1]6,243
Belgium	8,272	8,558	8,351	8,700
Bulgaria	[r]4,808	5,142	5,675	[1]5,952
Czechoslovakia	10,529	10,746	11,244	[1]11,310
Denmark	2,596	2,545	2,829	3,000
Finland	2,012	1,887	1,878	[1]1,928
France	32,401	31,779	30,892	[1]31,773
German Democratic Republic	[r]12,500	13,334	13,802	14,330
Germany, Federal Republic of	[r]37,646	35,544	37,433	[1]39,101
Greece	9,640	11,667	12,434	[1]13,336
Hungary	4,738	5,093	5,251	[1]5,357
Iceland	160	153	148	150
Ireland	1,730	1,759	1,891	2,200
Italy	40,044	41,580	41,621	44,250
Luxembourg	330	320	343	400
Netherlands	3,837	4,295	4,312	4,100
Norway	[r]2,960	2,572	2,369	[1]2,422
Poland	21,826	23,479	23,920	[1]21,138
Portugal	4,093	4,736	5,732	5,700
Romania	[r]14,427	15,295	16,191	[1]17,196
Spain (including Canary Islands)	[r]27,780	[2]30,859	[2]33,327	[1] [2]30,768
Sweden	[r]3,163	2,794	2,588	[1]2,579
Switzerland	3,909	4,022	4,075	4,000
U.S.S.R.	[r]136,957	140,055	139,944	[1]135,597
United Kingdom	17,394	17,037	17,540	[1]17,791
Yugoslavia	[r]8,400	8,826	9,588	[1]10,010
Africa:				
Algeria	[r]1,543	1,959	2,973	4,000
Angola[e]	[r]330	330	440	440
Cameroon	330	400	[e]390	400
Cape Verde Islands[e]	4	4	4	4
Egypt	3,706	3,590	3,307	3,600
Ethiopia	164	80	[e]95	[1]102
Gabon	118	210	210	220
Ghana	[e]720	672	551	440
Kenya	[r]1,087	1,261	1,240	1,030
Liberia	[e]110	[e]110	146	160
Libya	1,653	2,756	3,527	3,000
Madagascar	82	57	73	80
Malawi	94	104	103	[1]119
Mali	[e]55	38	37	40
Morocco	[r]2,573	3,164	3,107	4,400
Mozambique	239	356	[e]360	[1]301
Niger	[r]42	[e]45	[e]45	[1]42
Nigeria	[r]1,404	1,587	1,693	1,900
Rhodesia, Southern	595	542	450	[1]437
Senegal	425	364	393	[1]423

See footnotes at end of table.

Table 21.—Hydraulic cement: World production, by country —Continued

(Thousand short tons)

Country	1976	1977	1978[p]	1979[e]
Africa: —Continued				
South Africa, Republic of	7,769	7,245	7,522	7,600
Sudan	143	151	[e]188	190
Tanzania	266	287	255	[1]331
Tunisia	[r]526	631	972	[1]1,548
Uganda	[r]96	[e][r]90	[e]90	55
Zaire	[e]720	539	520	500
Zambia	[e]424	[e]440	135	220
Asia:				
Afghanistan[3]	[e]184	150	[e]140	150
Bangladesh	[r]173	338	376	340
Burma	[e]257	296	280	350
China:				
Mainland	44,100	59,250	71,898	[1]81,461
Taiwan	9.644	11,876	12,634	[1]13,114
Cyprus	1,130	1,184	1,220	[1]1,270
Hong Kong	843	1,134	1,364	[1]1,415
India	[r]20,547	21,010	21,561	[1]20,138
Indonesia	[r]1,988	2,952	[e]5,351	3,750
Iran	6,834	7,998	13,227	9,900
Iraq	[r]3,007	3,494	5,070	5,620
Israel	2,204	2,164	2,200	[1]2,116
Japan	75,742	80,620	93,550	[1]96,787
Jordan	588	624	622	[1]688
Kampuchea[e]	55	55	11	1
Korea, North	7,700	7,700	7,700	8,800
Korea, Republic of	13,087	15,648	16,681	[1]18,092
Kuwait	387	363	685	690
Lebanon	[e]1,878	1,499	1,522	1,500
Malaysia	1,917	1,959	2,420	2,400
Mongolia[e]	[r]175	175	110	110
Nepal	33	46	40	[1]24
Pakistan	3,459	3,489	3,420	[1]3,768
Philippines	4,965	4,875	5,116	5,100
Qatar	190	185	229	[1]261
Saudi Arabia	1,217	1,397	1,984	2,400
Singapore[e]	1,490	1,490	1,490	1,490
Sri Lanka	470	392	634	750
Syria	1,224	1,537	1,580	1,900
Thailand	[r]4,916	5,611	5,567	5,800
Turkey	[r]13,576	15,248	16.676	[1]15,199
Vietnam[e]	[r]815	903	937	926
Yemen	[e]66	66	69	100
Oceania:				
Australia	5,580	5,537	5,504	[1]5,779
Fiji Islands	76	85	106	[1]106
New Caledonia	60	55	[e]60	60
New Zealand	[r]1,102	1,004	880	[1]833
Total	[r]822,418	[r]872,894	938,095	957,791

[e] Estimate. [p] Preliminary. [r] Revised.

[1] Reported figure.

[2] Excludes natural cement.

[3] Year beginning March 21 of that stated.

TECHNOLOGY

Cement Manufacture.—Research and development efforts since the early 1970's have had a strong focus on improving energy efficiency in the manufacture of cement and efficient uses of cement in concrete products and structures.

Very active during this period was the National Materials Advisory Board's (National Research Council) Committee on the Status of Cement and Concrete Research and Development in the United States. The committee conducted a study to assess the status of cement and concrete research and development activity, to determine the factors causing the apparent present low level of activity, and to provide specific recommendations on where an increased research and development effort would produce the greatest benefits to the Nation. The study concluded that the U.S. cement and concrete research and development establishment has substantially deteriorated in comparison with its status 20 years ago and there is little likelihood that this will anticipate and meet the future's challenges and changed needs 15 to 20 years ahead.

Reinforced suspension preheater (RSP) systems have lower capital cost, reduced maintenace costs, better process stability, and low NOx-emissions. Specific advantages include the following: Swirl furnaces burn all fuels completely and handle high sulfur coals with low or high volatile content; ignition takes place in a clean-burning atmosphere, before raw materials are introduced; fuel is combusted completely in a swirl calciner; temperature conditions in the swirl furnace can be changed by varying the rate of raw material input; RSP design creates extra retention time; and 35% to 40% decarbonation is achieved in the swirl calciner.[37]

Plants under construction in the United States employing the RSP system include Marquette Cement Manufacturing Co., Cape Girardeau, Mo. (3,150 short tons per day); Kaiser Cement Corp., Permanente, Calif. (5,000 short tons per day); and Ideal Cement Co., Theodore, Ala. (4,650 short tons per day).

Research institutes in the U.S.S.R. carried out investigations which show that clinker burning conditions have the greatest effect on the hydraulic properties of clinker. Other factors include composition and fineness of raw feed, rate of cooling of the clinker, and particle size of the finished cement. It was found that if a raw material with a silicate component containing iron oxide is used it should be subjected to rapid clinker burning in a short kiln with a short flame. In a long kiln with a long sintering zone, it is possible to burn clinker with good hydraulic properties only if the alkali content is above 0.7% High early strength cements in the U.S.S.R. are produced from normally burned portland cement clinker and also with admixtures of halogen compounds.[38]

The manufacture of low-alkali cement from high-alkali raw materials has primarily been confined to the wet or the semiwet process of manufacture and to the use of raw materials suitable for making pellets of sufficient strength. The process was, in most cases, characterised by a very high water demand. Now it can be done by means of separate precalcining of the raw meal outside the kiln as a purely dry process of cement manufacture. Because of this, all the kiln waste gases can be discharged without necessitating an overall heat consumption of more than 850 to 900 kilocalories per kilogram of clinker. In this way, a minimum alkali content is achieved in the clinker solely by the volatitization of the alkali compounds. In addition, raw materials with a high content of sulfur and chloride can be used, and the system can be fired with fuels with a high sulfur content without causing problems in the plant operation. The discharge of all the kiln waste gases does not result in a lowering of the specific kiln output as compared with other precalcining systems. The process is suitable for the production not only of low-alkali cement, but also of cement with increased 28-day strength.[39]

Blended Cement.—A study was conducted to determine the effect of the chemistry of slags on the strength properties of cement-slag mixtures. The compressive strength of 192 laboratory cements containing 60% and 75% blast furnace slag made with two clinker compostitions and two degrees of fineness, were measured at ages ranging up to 91 days. The blast furnace slag cements were made with 24 granulated slags from different iron and steel plants using production methods that differed considerably from one another. These cements attained 28-day strengths ranging from 25 to 55 newtons per square millimeter. With the aid of the data thus collected, the applicability of some well-known formulas for calculating hydraulic activity was investigated statistically. None of the formulas gave generally valid information as to the effect of chemical composition for all the blast furnace slags of different origin envisaged here. Moreover, since further influencing factors are involved in production of such cements, simple formulas cannot be expected to yield useful predictions of probable strengths except when applied within narrow limits of composition of a blast furnace slag cement.[40]

In connection with the extension of the cement operations owned by Hoesch Hittenwerke, A. G., the firm developed a new process for the granulation of blast furnace slag. After intensive studies, a pilot plant was installed to operate with a blast furnace, and a new principle of water extraction and granulated slag handling was tried out. This new water extraction principle consists essentially in utilizing the precipitated granules as a filter layer, thus ensuring a high degree of mechanical purity in the effluent water. The most favorable water to slag ratio was determined to be that at which the granulated slag has a low residual moisture content along with a high content of glass. As the raw material for cement manufacture in this plant is treated by grinding in combination with drying, the low residual moisture was a particularly necessary condition. The most favorable results were obtained with a particle size range of up to 3 millimeters for the granulated slag, possessing a glass content of between 92% and 95%, and containing about 8% residual moisture. The good experience gained with the pilot plant led to the construction of two industrial plants associated with two back-pressure blast furnaces.[41]

Concrete.—New technology in concrete develops over a period of years, generally as a result of several years of study. Such studies start from a basic or laboratory level, progress through the pilot stage to full scale and then continue until field or service performance is demonstrated. Technological research and development in the field of concrete covers a very broad range of studies, and it is beyond the scope of this review to mention all of the numerous specific studies that have been in progress over the past 2 years.

Recent improvements in concrete production methods include development of computer-controlled construction equipment; self-contained units for continuous volumetric mixing of concrete; modification of mixing and batching procedures to permit successful incorporation of glass or steel fibers, or of superplasticizers; methods of production of polymer-impregnated concrete to meet special needs for chemical resistance; production of extruded hollow-core panels for floor and wall systems; construction methods for segmental cantilevered box-girder bridges; and special methods for the construction of massive fixed and floating marine storage units.

Widespread development of computer techniques has recently influenced the concrete area, and the development of mathematical models to describe nonlinear triaxial deformation, failure envelopes, creep, and certain moisture and thermal effects have been pursued with some success. Strength concepts have been placed on a statistical basis, and statistical quality control methods have been applied in monitoring concrete production. All of these developments have resulted in significant reductions in the safety factors used in designing concrete structures.

During the past few years, a start has been made toward producing "manufactured" concrete in semi-industrial environments with high production rates and relatively close dimensional tolerances. Intensive vibration and relatively short mixing cycles are frequently used. Better methods of monitoring the concrete during the processing and early post placement stages are being applied. Traditional quality control procedures, comprising after-the-fact testing of small specimens cast separately for testing purposes, are probably inadequate for such concretes.

Improved varieties of concrete and concrete constituents and new varieties of composites based on cement have been developed recently, at least partly in the United States. Some of these materials have been brought into limited commercial practice, but applications are not widespread.

A variety of cements, based loosely on portland cement but modified to achieve specific characteristics, have been developed. These materials include regulated-set cements, shrinkage-compensating and expansive cements, some very high-early-strength cements, and others.

New admixtures, particularly superplasticizers or high-range water reducers, have also been developed in recent years. Most of the products were developed in Europe and Japan and are still being imported in the United States. High-range water reducers are organic admixtures that disperse cement and drastically reduce the water content needed for mixing and placing concrete. Their use permits stronger and more durable concrete to be made or ordinary concrete to be made with less trouble and expense in placing and consolidation.

Development of so-called low-porosity cement concrete has proceeded slowly. Low-porosity concrete is made from ground clinker without gypsum addition, but incorporating special admixtures that permit placement at exceedingly low water contents. Such concretes seem to have significantly superior strength, dimensional stability, impermeability, and durability.

Research and development on alkali-resistant reinforcing glass fibers for use with cement has been undertaken by glass manufacturers in several countries including the United States. A number of glasses intended for the purpose have been patented and are being commercially exploited. Alkali-resistant glass fibers have been applied to a variety of thin-panel composites, typically incorporating cement and some sand but not coarse aggregate. These composites have found various architectural uses, but are not yet recommended for load-bearing applications because of the uncertainty of the retention of strength under weathering conditions.

Steel fibers have been used in concretes in a variety of ways. Novel and much more efficient forms of steel fiber have been developed, including fibers with deformations along their entire lengths and fibers with special end anchorages. The latter have been produced in parallel assemblages held together with a water-soluble glue. Use of such assemblages has almost eliminated previous mechanical problems of incorporating the fibers into the concrete mix.

Concretes and other composites with various unusual features for special applications have been developed in recent years. A good illustration is shrinkage-compensated concrete used in water impoundment structures, parking garages, and a few large building complexes where crack avoidance was recognized as a primary objective by the designer. Applications have been developed for ferrocement, mortars heavily reinforced with steel wire mesh sheets, especially in small ships and boats.

The major development in structural concrete in recent years has been prestressed concrete. The initial impetus was the postwar shortage and high cost of construction steel in Europe in the 1940's, and European investigators were early leaders. The U.S. concrete industry kept pace in prestressed concrete in some areas, notably prefabricated, prestressed units, and pioneered in others. Nevertheless, this country lagged in important areas, particularly in the use of post-tensioned concrete for large structures, and specifically in the cantilevered segmental box-girder bridge. In the early 1970's, changed economic factors led to further rapid progress in the United States, even in areas that previously had been neglected.

A development that started in Europe and was later applied and refined in this country is the design and construction of prestressed concrete nuclear reactor vessels. Other recent achievements include very tall concrete buildings (more than 70 stories) using high-strength concrete for columns and ocean oil-storage tanks made of concrete, the latter developed largely in Europe. Considerable development has occurred in hyperbolic paraboloid cooling towers, and in lightweight concrete large-span bridges, but unanswered questions remain in both areas. The use of prestressed concrete for piles in ocean ports has now become widespread. Prestressed concrete piling is now used for substantially all structures on the west and gulf coasts of the United States, and its use is spreading to Asia and the Middle East.

Analysis of concrete structures has been revolutionized by computer methods which have today permitted the development of a much more realistic design (especially for earthquake or other dynamic loads). Great improvements have been made in building codes, including the adoption of limit-state design and the consideration of previously neglected effects such as torsional loading on beams, cracking calculations, etc. Consideration of the behavior of simple structural members such as beams, columns, etc., has given way to analyses of more complex structural systems, including the joints. Codes are being revised on a much more frequent basis to take advantage of the new developments.[42]

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Chromium

By Norman A. Matthews[1] and John L. Morning[1]

Chromite consumption increased substantially in 1979 compared with that of 1978 and 1977 and reached the highest level since 1974. The consumption increase paralleled an increase in domestic ferrochromium production and a decline in ferrochromium imports. World chromite production peaked in 1977 and declined slightly in 1978 and 1979. Apparent total domestic demand, including secondary chromium from scrap, was 600,000 short tons in 1979, second only to that of 1974.

Although complete statistics are not available, it is probable that world demand for chromium was at a record high in 1979 based upon U.S. consumption and reported demand growth in Western Europe and Japan.

Table 1.—Salient chromite statistics

(Thousand short tons)

	1975	1976	1977	1978	1979
United States:					
Exports	139	124	187	23	27
Reexports	45	85	61	29	28
Imports for consumption	1,252	1,275	1,293	1,013	1,024
Consumption	881	1,006	1,000	1,010	1,209
Stocks, Dec. 31: Consumer	952	1,009	1,338	1,301	907
World: Production	9,136	[r]9,372	[r]10,172	9,920	10,498

[r]Revised.

Legislation and Government Programs.—Congress requested a reinvestigation of alleged injury to the domestic ferroalloy industry caused by imports of high-carbon ferrochromium at low prices. The International Trade Commission initiated the investigation in June 1978 and recommended protection for the industry by quotas or additional duties. Presidential Proclamation 4608, dated November 15, 1978, authorized by the Trade Act of 1974, provided a temporary duty increase of 4 cents per pound of chromium content on all material imported at exit port prices less than 38 cents per pound. The proclamation will expire on or before November 15, 1981.

In response to a petition by the U.S. Ferroalloy Association in December 1978, the U.S. Department of the Treasury made its final determination in the case of subsidized imports of ferroalloys from Spain and imposed countervailing duties of 2.4% to 3.36%, with the latter figure applying to high-carbon ferrochromium, effective January 1, 1980.

The stockpile policy bill, Public Law 96-41, Strategic and Critical Materials Stockpiling Revision Act of 1979, was signed into law on July 30, 1979. It provides for the procurement of materials not up to goals as funds accumulate from the sales of excess materials. The inventory levels of most chromium materials in the national stockpile are close to the current goals.

U.S. Government stockpile goals and inventories of chromium stockpile materials are shown in table 2.

The United States and the United Nations removed economic sanctions on products from Zimbabwe-Rhodesia in December

1979 after the establishment of a representative government and election of a prime minister. The U.S. Government phased out quotas on imports of stainless and tool steels from Western Europe and Japan over the interval July 1979 to February 1980.

There were no sales of Government stockpile excesses of chromium materials or deliveries on sales contracts from prior years.

In August 1978, the Environmental Protection Agency promulgated regulations regarding "Best Conventional Pollutant Control Technology." These regulations covered open and closed electric arc smelting furnaces with wet air pollution control devices, and electrolytic chromium production facilities.[2] Final regulations were pending at yearend. Waste water effluent pretreatment standards for the electroplating industry, published in May 1979, were relaxed with respect to small shops discharging less than 10,000 gallons of waste water per day.[3]

The Occupational Safety and Health Administration was investigating evidence relating to the safety or toxicity of hexavalent chromium compounds used in conversion coatings on steel or as pigments in paint coatings. The study focused on the exposure of workers involved in spray painting environments. The National Paint and Coatings Association cooperated in a study of the health experience of 2,000 workers identified in the spray application of chromate-containing paints in manufacturing plants.

INMETCO, a subsidiary of Inco United States Inc., commissioned a new plant in Ellwood City, Pa., in 1978 to recover nickel and chromium from steel plant particulate wastes. With a capacity of 40,000 tons of waste per year, which was achieved in late 1979, the plant produced about 25,000 tons of stainless pig containing 4,800 tons of recovered chromium and nickel from baghouse dusts, mill scale, and grinding swarf.

Table 2.—U.S. Government chromium stockpile material inventories and goals

(Thousand short tons)

National	Goal	Inventory by program, Dec. 31, 1979			
		National stockpile	Defense Production Act	Supplemental stockpile	Total
Chromite, chemical-grade	734	242	--	--	242
Chromite, metallurgical-grade	2,550	2,164	381	323	2,868
Chromite, refractory-grade	642	291	--	100	391
Ferrochromium, high-carbon	236	126	--	276	402
Ferrochromium, low-carbon	124	128	--	191	319
Ferrochromium-silicon	69	26	--	33	59
Chromium metal	10	--	--	4	4

DOMESTIC PRODUCTION

Except for a small quantity produced for export in 1976, domestic mine production of chromite ceased in 1961 when the last government production contract for stockpiling was phased out. American Chromium Co. was arranging financing in 1979 to develop a chromium prospect in Siskiyou County, Calif.

The United States continued as a major world consumer of chromite for the production of chromium ferroalloys and metal, chromium-containing basic refractories, and chromium chemicals. The principal producers of these products are shown in the table below. Three domestic ferrochromium plants changed ownership in July 1979 when Macalloy Inc. purchased the Charleston, S.C., plant of Airco Inc., and SKW Alloys Inc. (Federal Republic of Germany) purchased the facilities of Airco at Calvert City, Ky., and Niagara Falls, N.Y. The latter two plants were minor producers of chromium alloys along with silicon and manganese alloys. Macalloy also purchased the Airco ferroalloy plant at Vargon, Sweden; this facility was renamed Vargon Alloy AB and continued as the largest ferrochromium producer in Western Europe. PPG Industries, Inc. sold its plant at Corpus Christi, Tex., to Harrisons and Crosfield Ltd., a United Kingdom chemicals producer.

Principal producers of chromium products

Company	Plant
Metallurgical industry:	
Airco Alloys, Airco, Inc.[1]	Calvert City, Ky., Niagara Falls, N.Y., Charleston, S.C.
Chromium Mining & Smelting Corp	Woodstock, Tenn.
Foote Mineral Co	Keokuk, Iowa, and Graham, W. Va.
Interlake, Inc	Beverly, Ohio.
Prairie Metals and Chemicals, Inc	Prairie, Miss.
Satralloy Corp	Steubenville, Ohio.
Shieldalloy Corp., Div. of Metallurg, Inc	Newfield, N.J.
Union Carbide Corp	Niagara Falls, N.Y., Marietta, Ohio, Alloy, W. Va.
Refractory industry:	
Basic, Inc	Maple Grove, Ohio.
Corhart Refractories Co., Inc	Pascagoula, Miss.
Davis Refractories, Inc	Jackson, Ohio.
General Refractories Co	Baltimore, Md., and Lehi, Utah.
Harbison-Walker Refractories (a division of Dresser Industries, Inc.)	Hammond, Ind., and Baltimore, Md.
Kaiser Aluminum & Chemical Corp	Moss Landing, Calif., and Columbiana, Ohio.
North American Refractories, Co. Ltd	Womelsdorf, Pa.
Ohio Fire Brick Co	Jackson, Ohio.
Chemical industry:	
Allied Chemical Corp	Baltimore, Md.
Diamond Shamrock Corp	Castle Haynes, N.C.
PPG Industries, Inc.[2]	Corpus Christi, Tex.

[1] Plants sold in 1979; Charleston, S.C. ferrochromium plant now operated by Macalloy Inc.
[2] Plant now operated by Harrisons and Crosfield Ltd. (United Kingdom).

Table 3.—Production, shipments, and stocks of chromium ferroalloys and chromium metal

(Short tons)

Year and alloy	Production: Gross weight	Production: Chromium content	Shipments	Producer stocks, Dec. 31
1978:				
Low-carbon ferrochromium	15,082	10,407	20,325	5,878
High-carbon ferrochromium	160,619	101,190	174,105	26,347
Ferrochromium-silicon	23,710	8,536	31,831	13,138
Other[1]	19,241	11,545	19,943	2,597
Total	218,652	131,678	246,204	47,960
1979:				
Low-carbon ferrochromium	34,034	23,304	35,991	4,272
High-carbon ferrochromium	212,935	131,222	193,657	35,934
Ferrochromium-silicon	25,898	9,292	36,009	3,265
Other[1]	21,745	13,214	22,568	5,463
Total	294,612	177,032	288,225	48,934

[1] Includes chromium metal, exothermic chromium additives, and other miscellaneous chromium alloys.

CONSUMPTION AND USES

Domestic consumption of chromite ore and concentrates was 1.01 and 1.2 million tons in 1978 and 1979, respectively, with 1979 consumption at the highest level since 1974. Of the total chromite consumed, the metallurgical industry used 63%; the refractory industry, 17%; and the chemical industry, 24%. Respective percentages of approximately 60-20-20 have prevailed in recent years. The metallurgical industry, in consuming 774,000 tons of chromite, produced 300,000 tons of chromium alloys and metal. About 39% of the metallurgical ore had a chromium-to-iron ratio of over 3:1, 32% had a ratio between 2:1 and 3:1, and 33% had a ratio of less than 2:1. Chromite consumption increased substantially in 1979 compared with that of 1978 and 1977 because of increased demand for ferroalloys generally in developed countries which led to a reduction of exports to the United States.

Producers of chromite-bearing refractories consumed 237,000 and 193,000 tons of chromite in 1978 and 1979, respectively. The chemical industry consumed 239,200 and 242,200 tons of chromite in 1978 and 1979, respectively. Chromium consumed in producing sodium dichromate totaled 73,100 tons in 1978 and 74,000 tons in 1979. On a sodium dichromate equivalent basis, tonnages of chemicals approximated 175,300 in 1978 and 177,500 in 1979.

Chromium has a wide range of applications in the three consuming industries. Its use as an alloying element in stainless and higher alloyed heat and corrosion-resistant alloys comprised 69% of reported consumption; other principal uses were in full-alloy steels (17%), high-strength low-alloy steels, cast irons, and superalloys, (3% each), and other alloy systems (5%).

The refractory industry utilized chromium in the form of chromite for manufacturing refractory bricks, castables, and granular patching compounds for ferrous and nonferrous smelting furnaces. Consumption declined 15% in 1979 compared with that of 1978, probably because of the adoption of water-cooled panels in the upper walls of ultra-high-powered steelmaking electric arc furnaces and improvements in competitive tar-bonded magnesite and burned dolomite bricks for basic oxygen steelmaking furnaces.

The chemical industry consumed chromite for manufacturing sodium and potassium dichromate, which are base materials for a wide range of chemicals used in pigments, plating baths, and leather tanning compounds.

Expanding new uses for chromium included fabricated, stainless steel exhaust manifold systems for automobiles to replace cast iron, thereby reducing weight; and turbochargers for small-engined automobiles to maintain performance without sacrificing fuel efficiency. In the power-generation field, a growing application for stainless and higher alloyed corrosion resistant alloys was in the construction of large wet scrubbers for utility powerplants. The scrubbers remove SO_2 from coal combustion exhaust gases.

Table 4.—Consumption of chromite and tenor of ore used by primary consumer groups in the United States

Year	Metallurgical industry		Refractory industry		Chemical industry		Total	
	Gross weight (thousand short tons)	Average Cr_2O_3 (percent)	Gross weight (thousand short tons)	Average Cr_2O_3 (percent)	Gross weight (thousand short tons)	Average Cr_2O_3 (percent)	Gross weight (thousand short tons)	Average Cr_2O_3 (percent)
1974 --	904	47.0	295	35.2	251	44.8	1,450	44.2
1975 --	532	44.6	183	34.5	166	44.9	881	42.5
1976 --	597	43.4	202	35.0	207	44.8	1,006	42.0
1977 --	578	41.3	208	36.0	214	44.7	1,000	40.9
1978 --	534	39.8	237	36.6	239	45.3	1,010	39.9
1979 --	774	39.9	193	36.2	242	44.9	1,209	40.2

Table 5.—U.S. consumption by end use and form of chromium ferroalloys and metal

(Short tons, gross weight)

Year and end use	Low-carbon ferrochromium	High-carbon ferrochromium	Ferrochromium silicon	Other	Total
1978:					
Steel:					
Carbon	1,366	5,288	1,275	186	8,115
Stainless and heat-resisting	26,183	287,111	32,251	193	345,738
Full alloy	17,167	55,999	4,527	5,058	82,751
High-strength low-alloy and electric	1,647	8,669	2,167	1,740	14,223
Tool	1,738	4,708	89	2	6,537
Cast irons	1 170	13,520	134	866	15,690
Superalloys	4,934	6,941	210	3,070	15,155
Welding materials (structural and hard-facing)	876	1,244	--	383	2,503
Other alloys[1]	1,748	1,448	3	2,522	5,721
Miscellaneous and unspecified	2,748	492	76	53	3,369
Total	59,577	385,420	40,732	[2]14,073	499,802
Chromium content	40,389	233,297	14,983	9,307	297,976
Stocks, Dec. 31, 1978	6,455	69,196	3,492	[3]2,618	81,761
1979:					
Steel:					
Carbon	1,567	5,098	1,314	85	8,064
Stainless and heat-resisting	22,999	332,946	24,647	223	380,815
Full alloy	18,703	61,095	4,917	5,321	90,036
High-strength low-alloy and electric	1,477	7,156	3,163	1,830	13,626
Tool	1,543	3,804	42	7	5,396
Cast irons	1,490	13,304	235	529	15,558
Superalloys	6,744	6,854	175	3,553	17,326
Welding materials (structural and hard-facing)	986	1,091	--	559	2,636
Other alloys[1]	2,012	1,441	9	2,780	6,242
Miscellaneous and unspecified	2,738	413	72	31	3,254
Total	60,259	433,202	34,574	[2]14,918	542,953
Chromium content	41,020	259,676	12,722	10,115	323,533
Stocks, Dec. 31, 1979	6,683	45,465	3,701	[3]2,465	58,314

[1] Includes magnetic and nonferrous alloys.

[2] Includes 5,089 tons of chromium metal in 1978 and 5,940 tons in 1979.

[3] Includes 808 tons of chromium metal in 1978 and 1,063 tons in 1979.

STOCKS

Reported consumer stocks of chromite declined substantially during 1979 from 1.3 to 0.91 million tons, with most of the decline at ferroalloy production plants. Stocks of 1.3 million tons or higher have been normal since the end of 1976. A substantial part of the reported decline was associated with a change in ownership of the major ferrochromium production facility and its ore stocks. Producer stocks of ferroalloys were about double monthly shipments and were reasonably stable over the 2-year period. Consumer stocks of ferroalloys declined from 79,000 tons at the end of 1978 to 56,000 tons at the end of 1979, with all of the decline in the high-carbon ferrochromium category. Stocks of chromium chemicals at producing plants (sodium dichromate equivalent) decreased from 15,800 tons at the end of 1978 to 12,800 tons at the end of 1979.

Table 6.—Consumer stocks of chromite, December 31

(Thousand short tons)

Industry	1975	1976	1977	1978	1979
Metallurgical	701	762	900	755	416
Refractory	154	136	174	185	161
Chemical	97	111	264	361	330
Total	952	1,009	1,338	1,301	907

Table 7.—Consumer stocks of chromium ferroalloys and chromium metal, December 31

(Short tons, gross weight)

Product	1975	1976	1977	1978	1979
Low-carbon ferrochromium	10,974	10,100	6,247	6,455	6,683
High-carbon ferrochromium	50,076	52,553	66,114	69,196	45,465
Ferrochromium-silicon	4,418	3,995	4,777	3,492	3,701
Other[1]	2,352	3,300	2,228	2,618	2,465
Total	67,820	69,948	79,366	81,761	58,314

[1] Includes chromium briquets, chromium metal, exothermic chromium additives, and other miscellaneous chromium alloys.

PRICES

There were few price movements of chromite in 1978 and 1979. The Soviet chromite price was suspended in February 1978 and continued to be unquoted at yearend 1979. At the beginning of 1978, the published price of South African Transvaal chromite was $56 to $61 per metric ton. The quotation was lowered to $54 to $58 per metric ton in February 1978 where it remained throughout 1979. Turkish chromite, 48% Cr_2O_3, 3 to 1 chromium-to-iron ratio, was quoted at $132 to $142 per metric ton at Turkish ports in January 1978. In February, the quotation was changed to $143 per metric ton, but was lowered to $105 per ton in June because of lack of sales. In January 1979, the price was increased to $110 per metric ton where it remained for the balance of the year.

Ferrochromium prices trended upward during the 2-year interval as prices for most chromium products increased 20% to 30%. Chromium alloys and chromium metal prices as published in Metals Week follow:

Material	January 1978	January 1979	December 1979
	(Cents per pound chromium)		
U.S. charge chromium (50%-55% chromium)	40	43-44	44.25-45
Imported charge chromium (50%-55% chromium)	32-33	40-44	42.75-45
Imported charge chromium (60%-65% chromium)	34-36.5	36.5-39.5	48-52
U.S. charge chromium (66%-70% chromium)	41	41-45	45-53
U.S. low-carbon ferrochromium (0.025% carbon)	80	80	95
U.S. low-carbon ferrochromium (0.05% carbon)	75	74-78	90
Imported low-carbon ferrochromium (0.05% carbon)	55-58.5	75	89-95
Simplex (low-carbon ferrochromium)	75	80	90
	Cents per pound of product		
Ferrochromium-silicon	29.45-32	29.32-29.47	34.5-44.25
Aluminothermic chromium metal	263	299	--
Electrolytic chromium metal	263-279	299	350

FOREIGN TRADE

Exports of chromite in 1978 and 1979 were modest in the absence of deliveries from prior sales of excess Government stockpile material. Reexports of chromite ore were also considerably lower than in prior years. Ferrochromium exports were 19,397 and 14,762 tons in 1978 and 1979, respectively; Canada (35%), Spain (21%), and mainland China (19%) were the leading recipients.

Exports of chromium chemicals and pigments were valued at $28.8 million in 1978 and $40.8 million in 1979. Gross tonnages exported in 1978 and 1979, respectively, were potassium chromate and dichromate, 10 and 62; sodium chromate and dichromate, 15,012 and 24,360; chromic acid, 6,795 and 6,326; and chromium pigments, 3,677 and 3,192. Most of the exports went to Canada, Japan, the Republic of Korea, and to Central and South American countries.

Imports of chromite were about 1 million tons each in 1978 and 1979. Tonnages imported in 1979 declined from the Republic of South Africa and Finland and increased from Albania and Turkey compared with those imported in 1978. Value of all chromite imports was $51.3 and $55.6 million in 1978 and 1979, respectively, reflecting the modest increase in prices.

Ferrochromium imports in 1978 were a record 313,546 tons, compared with 224,082 tons imported in 1977. Over 95% was the high-carbon (charge) type, with most of the volume from the Republic of South Africa and Yugoslavia. Ferrochromium imports in 1979 declined to 242,450 tons, with most of the reduction in charge ferrochromium from South Africa.

Chromium chemicals, compounds, and pigments imported were valued at $14.7 million in 1978 and $14.9 million in 1979. Gross tonnages imported in 1978 and 1979, respectively, were potassium chromate and dichromate, 670 and 381; sodium chromate and dichromate, 611 and 579; chromic acid, 98 and 0.4; chromium carbide, 215 and 200; and pigments, chrome green, 91 and 40; chrome yellow, 1,257 and 1,368; chrome oxide green, 3,901 and 2,868; molybdenum orange, 336 and 411; strontium chromate, 333 and 230; and zinc yellow, 1,547 and 1,867. Major supplier countries were the Federal Republic of Germany, Canada, the United Kingdom, Brazil, Norway, and Japan.

Table 8.—U.S. exports and reexports of chromite ore and concentrates

(Thousand short tons and thousand dollars)

Year	Exports		Reexports	
	Quantity	Value	Quantity	Value
1976	124	5,509	85	5,475
1977	187	10,105	61	4,913
1978	23	2,767	29	2,574
1979	27	2,514	28	2,860

Table 9.—U.S. imports for consumption of chromite, by grade and country

(Thousand short tons and thousand dollars)

Year and country	Less than 40% Cr_2O_3			More than 40% but less than 46% Cr_2O_3			46% or more Cr_2O_3			Total		
	Gross weight	Cr_2O_3 content	Value	Gross weight	Cr_2O_3 content	Value	Gross weight	Cr_2O_3 content	Value	Gross weight	Cr_2O_3 content	Value
1978:												
Albania	--	--	--	43	19	2,592	--	--	--	43	19	2,592
Canada	25	8	1	--	--	--	--	--	--	25	8	1
Finland	69	23	3,163	--	--	--	--	--	--	69	23	3,163
Philippines	185	60	10,710	--	--	--	--	--	--	185	60	10,710
South Africa, Republic of	6	2	331	382	168	17,810	102	49	5,117	490	219	23,258
Turkey	60	21	3,460	--	--	--	9	4	818	69	25	4,278
U.S.S.R	149	57	6,705	--	--	--	8	4	728	157	61	7,433
Total[1]	494	171	24,370	425	186	20,402	119	58	6,662	1,088	415	51,434
1979:												
Albania	11	4	674	96	41	5,787	--	--	--	106	45	6,461
Finland	21	6	668	10	4	442	--	--	--	31	10	1,110
Madagascar	--	--	--	--	--	--	20	10	2,000	20	10	2,000
Philippines	194	62	11,808	--	--	--	--	--	--	194	62	11,808
South Africa, Republic of	10	4	435	269	120	12,382	74	35	3,633	353	159	16,450
Turkey	9	3	540	17	8	1,439	44	21	3,878	70	32	5,857
U.S.S.R	227	88	10,781	23	10	1,137	--	--	--	250	98	11,918
Total	472	167	24,906	414	183	21,187	138	66	9,511	1,024	416	55,604

[1] Data may not add to totals shown because of independent rounding.

Table 10.—U.S. imports for consumption of ferrochromium, by country

Year and country	Low-carbon ferrochromium (less than 3% carbon)			High-carbon ferrochromium (3% or more carbon)		
	Gross weight (short tons)	Chromium content (short tons)	Value (thousands)	Gross weight (short tons)	Chromium content (short tons)	Value (thousands)
1978:						
Belgium-Luxembourg	--	--	--	56	38	43
Brazil	--	--	--	6,284	3,478	1,913
Canada	--	--	--	22	13	25
France	922	666	815	--	--	--
Germany, Federal Republic of	4,295	3,091	4,097	519	350	398
Italy	283	205	246	--	--	--
Japan	2,620	1,742	2,133	174	116	120
Norway	2,179	1,441	1,800	667	450	322
South Africa, Republic of	111	64	58	257,493	136,858	77,018
Sweden	5,357	3,787	4,955	3,647	2,360	1,610
Turkey	--	--	--	2,598	1,740	996
Yugoslavia	276	198	154	39,483	25,709	16,829
Total	16,043	11,189	14,258	310,943	171,112	99,274
1979:						
Belgium-Luxembourg	18	10	10	--	--	--
Brazil	--	--	--	7,330	4,037	2,759
France	1,131	808	1,288	--	--	--
Germany, Federal Republic of	3,739	2,672	4,000	111	75	107
Italy	37	27	38	--	--	--
Japan	2,943	1,998	3,522	--	--	--
Norway	321	195	263	221	150	114
South Africa, Republic of	2,645	1,527	1,680	174,320	91,780	70,203
Sweden	8,695	6,133	10,104	4,227	2,717	2,203
Turkey	1,102	750	1,349	2,796	1,820	1,464
Yugoslavia	--	--	--	82,827	21,260	17,487
Total	20,631	14,120	22,254	221,832	121,839	94,337

Tariffs.—The Tokyo round of multilateral trade negotiations was completed in 1979, resulting in new tariff agreements with the developed nations of the world. Tariff rates for chromium commodities at the beginning (January 1, 1980) and ending (January 1, 1987) dates of the staging period, as published in the Tariff Schedules of the United States, Annotated (1980), are shown below.

Item	Number	Most Favored Nation (MFN)		Non-MFN
		Jan. 1, 1980	Jan. 1, 1987	Jan. 1, 1980
Ore and concentrate	601.15	Free.	Free.	Free.
Low-carbon ferrochromium	606.22	4% ad valorem.	3.1% ad valorem.	30% ad valorem.
High-carbon ferrochromium	606.24	.625 per lb. of chromium.[1]	No change.	25% ad valorem.
Ferrosilicon chromium	606.42	10% ad valorem.	10% ad valorem.	Do.
Sodium chromate and dichromate	420.98	2.8% ad valorem.	2.4% ad valorem.	8.5% ad valorem.
Potassium chromate and dichromate	420.08	1.6% ad valorem.	1.5% ad valorem.	3.5% ad valorem.
Chromium carbide	422.92	5.8% ad valorem.	4.2% ad valorem.	25% ad valorem.
Pigments:				
Chrome green	473.10	5% ad valorem.	5% ad valorem.	Do.
Chrome yellow	473.12	do	do	Do.
Chromium oxide green	473.14	4.8% ad valorem.	3.7% ad valorem.	Do.
Hydrated chromium oxide green	473.16	do	do	Do.
Molybdenum orange	473.18	5% ad valorem.	5% ad valorem.	Do.
Strontium chromate	473.19	4.8% ad valorem.	3.7% ad valorem.	Do.
Zinc yellow	473.20	5% ad valorem.	5% ad valorem.	Do.

[1] Total duty of 4.625 cents per pound on material valued less than 38 cents per pound of chromium through Nov. 15, 1981.

WORLD REVIEW

A domestic natural resource company and a major Japanese stainless steel manufacturer joined in a study of the economic viability of mining chromite black sands in Southwest Asia. No new expansion plans for ferrochromium production were announced in the Republic of South Africa, but Greece, India, the Malagasy Republic, and the Philippines expressed intent to establish substantial new ferrochromium production capacity.

The Government of the Federal Republic of Germany approved a plan for assistance to industry in establishing a 1-year stockpile for five key raw materials including chromium. France announced that it planned further purchases of mineral raw materials, including chromium, to build a 2-month supply over a 5-year period. Japan has a modest ferrochromium stockpile and was considering methods for establishing a broader coverage of raw materials.

The European Economic Community imposed quotas on a quarterly basis for the importation of high-carbon ferrochromium to the member countries, starting in mid-1978. The quotas increased at 6-month intervals and tonnages exceeding the quotas were assessed additional import duties.

Albania.—Albania has become the second largest exporter of chromite since the decline in exports from the U.S.S.R. after 1977. Following severance of close commercial ties with mainland China in 1978, more of the exports were being marketed in Europe and the United States. Three relatively new ferrochromium plants, constructed with Chinese assistance, will consume perhaps 25% of the total chromite production. The plants should reach capacity of 100,000 tons annually in 1980 and will supply the enlarged Elbasan steel plant and metallurgical complex.

Brazil.—Brazilian production of chromite has trended upward since 1974, and Brazil has become a substantial exporter of lump ore, concentrate, and high-carbon ferrochromium. Most of the ore requires beneficiation, typically to 48% Cr_2O_3 content. Cia. Ferro Ligas da Bahia S.A. (Ferbasa), the principal domestic producer, joined with Kloeckner Werke AG of the Federal Republic of Germany, in a new project to produce up to 65,000 tons of concentrates annually from Ferbasa concessions in Bahia State. Minas Gerais State Geological Center and Sao Paulo State Aerospace Center were working on improved methods for beneficiating ore types typically found in Minas Gerais and Bahia, respectively.

Finland.—Outokumpu Oy continued to expand production from the Kemi mine in north Finland. A second open pit was developed in 1978. The 27% Cr_2O_3 ore, mined at an annual rate of over 800,000 tons, was beneficiated by washing, grinding, and magnetic separation to a 44% Cr_2O_3 concentrate. Over half the production was consumed by the ferrochromium and stainless steel plants at Tornio. The latter was being expanded. A second sizable chromite deposit of lower grade was being explored near Sodankyla, 150 miles northeast of the Kemi mine.

Greece.—Intensive exploration has been conducted since 1976 for several classes of minerals, with particular emphasis on chromite. Resources have been mapped and beneficiation studies conducted to determine if the relatively low-grade deposits, particularly in the Vourinos Mountain area near Kozani, can support a ferrochromium industry. A beneficiation plant was planned by 1981 to supply a ferrochromium plant of 33,000 tons annual capacity by 1983.

India.—Chromite ore reserves were officially stated as 17.3 million metric tons, principally in Orissa. However, recent intensive exploration efforts by the Geological Survey of India and Minerals Exploration Corp. suggest reserves as high as 31 million metric tons in the Sukinda area of Orissa alone. Production of chromite declined in 1978 and 1979 compared with prior years because price increases resulted in the loss of most Japanese business. Some success was achieved in developing alternate markets in mainland China and Western Europe. Orissa Mining Corp. received bids from Outokumpu Oy (with collaboration by Voest-Alpine of Austria) and Showa Denko (with the German partner Kloeckner Werke AG) for construction of a 55,000-ton-per-year charge ferrochromium plant incorporating the latest technology to permit use of natural and beneficiated ore fines. A second small ferrochrome plant of 6,600-ton annual capacity was planned by Mysore Minerals Ltd. in Karnataka with technical assistance from Showa Denko.

Japan.—The viability of the Japanese high-carbon ferrochromium industry was challenged by rapidly increasing imports from the Republic of South Africa; during most of 1979, legislation to impose quotas was under consideration. Stockpiling was also under study by the Ministry of International Trade and Industry; the materials to be covered were so broad and expensive (including iron ore and coking coal) that no agreement was reached on a financing approach. Ferrochromium imports in 1979 approximated 280,000 tons, 75% from the Republic of South Africa, and domestic production was about 382,000 tons.

Madagascar.—Exploration delineated additional reserves of 4 million tons at the Bemanevika deposits near Andriamena. C. Itoh of Japan and Péchiney Ugine Kuhlmann continued joint exploration to develop reserves to support ore production of up to 300,000 tons annually.

New Caledonia.—New Caledonia continued to produce small quantities of chromite. The President of France, on a visit in mid-1979, promised to accelerate efforts to define the chromite production potential. Inco completed an evaluation of an old chromite deposit at Tiebaghi by deep drilling extensions of the ore body, but no decision on development by the company and its French partners was announced.

Papua New Guinea.—Significant exploration was conducted in the southwestern Pacific Islands. AMAX Exploration Inc. formed a joint venture with Kawasaki Steel Corp. of Japan to thoroughly explore prospects held by AMAX between Salamaua and Salua on the coast of Papua New Guinea. Chromiferous beach sands on the coast of the Island of Sulawesi and the Halmehera Group in Indonesia were also being investigated.

Philippines.—Production of chromite declined in 1978 because of large producer and customer inventories, but rebounded to a record level in 1979. Voest-Alpine of Austria acquired a substantial financial interest in Acoje Mining Co., the largest producer of metallurgical-grade ore in the Philippines. A new ferrochromium smelter of 35,000 tons annual capacity was planned at Phividec to be in operation by 1982. Alamag Processing Corp., a subsidiary of Bayer AG of the Federal Republic of Germany, received approval to construct a $12 million chemical-grade ore concentrate plant by 1983, with initial capacity of 33,000 tons annually, increasing to 100,000 tons by 1985. Site location and mining company affiliate were not announced. Alpha Integrated Mineral Resources filed an application to start mining metallurgical-grade chromite on Dinagat Island off Surigao del Norte. The $2 million beneficiation mill will have an annual capacity of 34,000 tons of concentrate and an assured market in Japan for 5 years. Island Mining and Industrial Corp. reported a major chromite discovery of metallurgical quality grading 47% Cr_2O_3 in the Bicobian area of Isabela Province in north Luzon.

South Africa, Republic of.—Recently revised estimates of chromite reserves to minable depths are 3.3 billion tons in the Bushveld Complex grading in excess of 35% Cr_2O_3. There were 17 producing mines in 1979 with an annual capacity in excess of 4.4 million tons and production was reported at a record 3.6 million tons of ore and concentrate. Ferrochromium production was centered in six major charge-chromium plants, two of which also produce low-carbon grades. Ferrochromium capacity approximates 800,000 tons per year with exports exceeding 660,000 tons in 1979.

The third furnace of the Union Carbide Corp. — General Mining and Finance Corp. plant at Tubatse started production in May 1978, giving an annual plant capacity of 140,000 tons of charge chromium. Consolidated Metallurgical Industries Ltd. commissioned the second furnace at the new Lydenburg smelter in 1979, providing a capacity of 150,000 tons annually. The process involves new technology incorporating prereduced pellets, an improvement introduced by Showa Denko of Japan to increase productivity and reduce power consumption in the smelting furnace.

The modernization of the Gravally mine beneficiation plant was completed; it produces a concentrate of 2.4 to 1 chromium-to-iron ratio which is in demand to blend with local ores. The mine and plant were operated by SA Manganese AMCOR. Armco Inc. signed an agreement in 1978 with Vereeniging Refractories Ltd. to establish a chromite mining operation in the Transvaal. Production is to begin in 1980 at an annual rate of 150,000 tons of concentrates.

Sudan.—Sudan has been a longtime minor producer of chromite; shipments totaled 20,000 tons in 1978. Mitsubishi of Japan conducted a 2-year study concerning mine modernization in the Ingessana Hills area and the feasibility of constructing a ferrochromium production facility. Mine modernization was taking place in 1979. Planned chromite production capacity was expected to increase to about 100,000 tons annually by 1981.

Turkey.—Turkish production of chromite in 1978 and 1979 remained relatively low because of general oversupply and price competition.

U.S.S.R.—The 1978 Soviet plan called for an increase of crude chromite ore capacity of 700,000 tons, including accelerated development of the Molodezhnaya underground mine and attainment of the design capacity of the concentrator in the Douskoye mining and concentration complex in western Kazakhstan. Production of chromite in 1979 was estimated at 2.6 million tons.

Zimbabwe-Rhodesia.—United Nations and United States sanctions against importation of Rhodesian chromium products were lifted in December 1979. Union Carbide Corp. resumed management of its affiliate, Union Carbide Rhomet, and expected to market the ferrochromium product in the United States starting in the first quarter of 1980. There were reports of damage to Rhodesian production facilities, but it was expected that exports will increase substantially in 1980. Salisbury Portland Cement Co. applied to the Mining Affairs Board to explore a large area near Makwiro on the Great Dyke for chromite, copper, nickel, and platinum metals. Anglo American Corp. conducted extensive tests to utilize Rhodesian ore fines effectively and selected briqueting as the most effective method. A prototype plant was completed at Gnelo in the Midlands in early 1978. Lime and binder molasses from adjoining sugar estates are mixed with ore fines to form the briquets.

Table 11.—Chromite: World production, by country

(Thousand short tons)

Country[1]	1976	1977	1978[p]	1979[e]
Albania[e] [2]	[r]915	970	1,100	1,220
Brazil	205	342	297	330
Colombia[e]	[r]6	6	6	6
Cuba[e]	35	35	35	35
Cyprus	[r]10	16	17	20
Egypt	[r] [e]([3])	--	1	--
Finland[4]	[r]193	186	196	210
Greece[5]	38	[e] [r]46	[e]44	60
India	443	389	293	300
Iran[e]	176	257	218	150
Japan	24	20	10	10
Madagascar	245	182	152	150
New Caledonia	11	9	9	9
Pakistan	12	9	12	10
Philippines	[r]475	593	592	620
Rhodesia, Southern[e]	[r]952	[r]747	[r]527	[r]597
South Africa, Republic of	2,656	3,372	3,466	[e]3,634
Sudan	24	19	20	20
Thailand	--	1	([3])	([3] [6])
Turkey[e] [7]	[r]640	[r]560	410	500
U.S.S.R.[e]	2,300	2,400	2,500	2,600
Vietnam[e]	10	[r]11	13	15
Yugoslavia	2	2	[e]2	2
Total	[r]9,872	[r]10,172	9,920	10,498

[e]Estimate. [p]Preliminary. [r]Revised.

[1] In addition to the countries listed, Bulgaria and North Korea may also produce chromite, but output is not reported quantitatively and available general information is inadequate for formulation of reliable estimates of output levels.

[2] Figures represent crude ore output, not marketable production.

[3] Less than 1/2 unit.

[4] Series revised to reflect marketable ore output (figures in previous editions represented crude mine product).

[5] Exports of direct-shipping ore plus production of concentrates.

[6] Reported figure.

[7] Estimated production of marketable product (direct-shipping ore plus concentrates) based on reported production of run-of-mine ore, which was as follows in thousand short tons: 1976-1,025; 1977-1,006; 1978-(estimated) 700; 1979-(estimated) 900.

TECHNOLOGY

Concern with the importance of chromium in the economy and import dependence of the United States was reflected in many studies, including that of the National Materials Advisory Board, which recommended increased efforts to conserve chromium, basic research to develop substitutes for chromium-containing alloys, and more exploration effort and incentives to develop North American resources. The committee considered design, metals processing, and substitution factors in its analysis of chromium utilization and possibilities for conservation.[4]

Two major contracts, funded by the U.S. Department of Energy, were awarded to gas turbine designers to develop automotive gas turbine engines by 1985 with improved fuel efficiency, achieved through higher turbine inlet temperatures and critical ceramic components. Electrochemists at General Motors Corp. Research Laboratories announced the development of high-speed electroplating techniques which increase chromium plating rates 60-fold for industrial and decorative applications by minimizing the gap between anode and cathode and rapid circulation of the electrolyte.

The Bureau of Mines continued research on (1) chromium from domestic resources, (2) reclamation of chromium from industrial wastes, and (3) the development of new alloy systems to conserve chromium in corrosive aqueous and high temperature environments. Laboratory-scale investigations defined the principles for recovery of chromium values from the leaching residues produced after removal of nickel and cobalt in the treatment of western laterites. Results were published covering process research scale operations in the treatment of liquid chromic acid-sulfuric acid etchant wastes, which normally are neutralized and discarded as undesirable materials in landfills.[5] A key step in the purification process is the use of a diaphragm electrolytic cell with two anode chambers.

Bureau-contracted investigations dealt with the utility of high-manganese austenitic alloys, modified with silicon and aluminum for oxidation resistance, as substitutes for chromium-nickel heat-resistant alloys.

Plasma smelting for iron recovery from steelmaking particulate wastes has been under investigation for several years in Canada, supported by the Government of Canada, and the United Kingdom. Many advantages were claimed for direct ironmaking and for the production of ferrochromium.[6] A 1,400-kva furnace was constructed for extensive trials. The advantages of pelletizing the feed in the production of ferrochromium, in some cases in conjunction with prereduction, have been increasingly accepted with the latest installations in the Republic of South Africa, Finland, Zimbabwe-Rhodesia, and the Federal Republic of Germany.

Two classes of ferritic stainless steels (18% Cr; 2% Mo and 27% Cr; 1% to 4% Mo) were developed to the stage of significant commercial acceptance after a decade of trials. The favorable corrosion resistance characteristics of the alloys together with control of the interstitial elements, carbon and nitrogen, permit use in a variety of applications and product forms with satisfactory forming characteristics.

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[1] Physical scientist, Section of Ferrous Metals.

[2] Environmental Protection Agency. Best Conventional Pollutant Control Technology. Federal Register, Aug. 23, 1978, pp. 37570-37607.

[3] Environmental Protection Agency. Development Document for Existing Source Pretreatment Standards for Electroplating Point Source Category. DTA 440-1-79-003, August 1979.

[4] National Materials Advisory Board, National Research Council. Contingency Plans for Chromium Utilization. NMAB-335, 1978, 347 pages.

[5] Soboroff, D. M., J. D. Troyer, A. A. Cochran. Regeneration and Recycling of Waste Chromic Acid - Sulfuric Acid Etchants. BuMines RI 8377, 1979, 13 pages.

[6] Gulliver, P. L., and P. J. F. Gladman. The Application of the Expanded Precessive Plasma System to the Steel Industry. Presentation to the Congress of the United States, Office of Technology Assessment, February 1979.

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Clays

By Sarkis G. Ampian[1]

Clays in one or more of six classification categories (kaolin, ball clay, fire clay, bentonite, fuller's earth, or common clay and shale) were produced in 46 States and Puerto Rico during 1979. Clay production was not reported in Alaska, Hawaii, the District of Columbia, Rhode Island, or Vermont. The States leading in output were Georgia, 8.3 million tons; Texas, 3.9 million tons; Wyoming, 3.5 million tons; and North Carolina and Ohio, 3.4 million tons each; followed in order by Alabama, and California. Georgia also led in total value of clay output with $437.6 million; Wyoming was second with $75.0 million. Compared with 1978 figures, clay production increased in 17 States and value increased in 36 States. Total quantity of clays sold or used by domestic producers in 1979 was 4% lower; total value rose 18% to an alltime high. Increases in value per ton were reported for all clays in 1979 owing to increased labor, fuel, and material costs. The energy crisis, or more specifically, the increasing shortage and costs of fuels, continued to cause considerable concern among clay producers and clay product manufacturers. Industrywide efforts were made both to economize and to obtain standby fuels. The costs of environmental protection equipment and environmental restrictions and rising capital costs also continued to adversely affect production during 1979.

Production of the specialty clays, kaolin, ball clay, and fuller's earth all increased with the exception of bentonite and fire clay, which, together with common clay and shale, showed decreased production. A small downturn in construction that lowered demand for building materials (brick, lightweight aggregate, vitrified clay pipe, clay floor and wall tile, etc.) was responsible for the decline in production of common clay and shale. Production of kaolin increased 11%; ball clay, 5%; and fuller's earth, 3%. Bentonite and fire clay decreased 1% and 6%, respectively, largely because of a downturn in the economy which lowered the demand for steel products and refractories.

Kaolin in 1979 accounted for only 14% of the total clay production but for 55% of the value.

Table 1.—Salient clay and clay products statistics in the United States[1]

(Thousand short tons and thousand dollars)

	1975	1976	1977	1978	1979
Domestic clays sold or used by producers:					
Quantity	49,047	52,389	53,196	56,822	54,689
Value	$424,556	$528,745	$579,170	$717,274	$846,089
Exports:					
Quantity	2,315	2,487	2,561	2,665	3,205
Value	$120,298	$151,953	$160,790	$194,914	$243,722
Imports for consumption:					
Quantity	38	39	36	25	51
Value	$1,947	$1,814	$1,917	$2,082	$3,972
Clay refractories, shipments: Value	$409,879	$448,471	$465,442	$497,567	$580,257
Clay construction products, shipments: Value	$655,779	$783,644	$993,508	$1,158,278	$1,179,058

[1] Excludes Puerto Rico.

Table 2.—Clay sold or used by producers in the United States in 1978, by State[1]

(Short tons)

State	Ball clay	Ben-tonite	Common clay and shale	Fire clay	Fuller's earth	Kaolin	Total	Total value
Alabama	--	W	2,094,447	422,557	--	264,719	[2]2,781,723	[2]$24,884,908
Arizona	W	35,802	W	W	--	--	142,810	731,189
Arkansas	--	--	1,077,884	--	--	59,365	1,137,249	5,119,310
California	317	87,725	2,327,267	--	--	63,725	2,479,034	15,106,031
Colorado	--	W	500,486	47,040	--	--	[2]547,526	[2]2,753,433
Connecticut	--	--	105,243	--	--	--	105,243	324,210
Delaware	--	--	10,449	--	--	--	10,449	7,837
Florida	--	--	118,393	--	453,527	28,755	600,675	28,849,655
Georgia	--	--	2,325,527	--	618,805	5,531,835	8,476,167	358,653,559
Idaho	--	W	W	W	--	W	26,777	147,785
Illinois	--	--	698,780	42,790	W	--	[3]741,570	[3]3,185,048
Indiana	--	--	1,275,774	985	--	--	1,276,759	2,494,530
Iowa	--	--	894,087	--	--	--	894,087	2,694,011
Kansas	--	W	1,160,719	--	--	--	[2]1,160,719	[2]2,314,449
Kentucky	W	--	632,933	42,817	--	--	[4]675,750	[4]2,671,675
Louisiana	--	--	516,859	--	--	--	516,859	4,785,755
Maine	--	--	99,831	--	--	--	99,831	163,895
Maryland	W	--	948,421	--	--	--	[4]948,421	[4]2,642,315
Massachusetts	--	--	155,041	--	--	--	155,041	332,939
Michigan	--	--	2,121,707	--	--	--	2,121,707	6,993,043
Minnesota	--	--	174,420	--	--	W	[5]174,420	[5]2,089,514
Mississippi	W	356,265	1,356,174	--	W	--	1,959,559	19,622,829
Missouri	--	--	1,434,216	772,833	W	51,412	[3]2,258,461	[3]16,879,690
Montana	--	181,257	35,123	706	--	--	217,086	3,699,330
Nebraska	--	--	146,314	--	--	--	146,314	417,837
Nevada	--	8,756	W	--	W	W	50,731	513,730
New Hampshire	--	--	W	--	--	--	W	W
New Jersey	--	--	52,213	15,847	--	--	68,060	375,738
New Mexico	--	--	64,672	W	--	--	[6]64,672	[6]108,072
New York	W	--	658,769	--	--	--	[4]658,769	[4]2,121,131
North Carolina	--	--	3,542,473	--	--	W	[5]3,542,473	[5]9,067,127
North Dakota	--	--	W	--	--	--	W	W
Ohio	--	--	2,972,833	805,647	--	--	3,778,480	15,394,261
Oklahoma	--	--	1,019,460	--	--	--	1,019,460	1,874,322
Oregon	--	--	140,265	--	--	--	140,265	261,194
Pennsylvania	--	--	1,937,265	633,763	--	W	[5]2,571,028	[5]18,175,134
Puerto Rico	--	--	285,522	--	--	--	285,522	544,065
South Carolina	--	--	1,573,869	--	W	784,638	[3]2,358,507	[3]22,537,630
South Dakota	--	W	215,850	--	--	--	[2]215,850	[2]267,738
Tennessee	662,235	W	987,797	--	W	--	1,759,734	21,718,849
Texas	W	55,419	3,954,650	50,287	W	W	4,188,845	19,818,416
Utah	--	6,920	252,652	W	W	--	264,693	913,082
Virginia	--	--	1,043,369	--	--	--	1,043,369	3,266,027
Washington	--	--	356,771	W	--	--	[6]356,771	[6]1,417,738
West Virginia	--	--	343,114	W	--	--	[6]343,114	[6]574,887
Wisconsin	--	--	W	--	--	--	W	W
Wyoming	--	3,452,386	179,579	--	--	--	3,631,965	66,975,003
Undistributed	[7]273,699	[7]281,075	[7]283,520	[7]290,681	[7]457,287	[7]188,865	[8]1,110,935	[8]24,329,113
Total	936,251	4,467,605	40,074,738	3,125,953	1,529,619	6,973,314	57,107,480	717,818,034

W Withheld to avoid disclosing company proprietary data; included with "Undistributed."

[1] Includes Puerto Rico.

[2] Excludes bentonite.

[3] Excludes fuller's earth.

[4] Excludes ball clay.

[5] Excludes kaolin.

[6] Excludes fire clay.

[7] Total of States indicated by symbol W.

[8] Incomplete total; difference included with individual State totals.

Table 3.—Clay sold or used by producers in the United States in 1979, by State[1]

(Short tons)

State	Ball clay	Bentonite	Common clay and shale	Fire clay	Fuller's earth	Kaolin	Total	Total value
Alabama	--	W	1,858,715	247,257	--	465,510	[2]2,571,482	[2]$33,823,852
Arizona	W	28,176	W	--	--	--	188,421	642,162
Arkansas	--	--	912,215	--	--	132,015	1,044,230	7,685,510
California	452	81,160	2,389,278	--	--	60,032	2,530,922	18,621,176
Colorado	--	W	479,365	41,897	--	--	[2]521,262	[2]2,717,230
Connecticut	--	--	111,578	--	--	--	111,578	434,701
Delaware	--	--	10,800	--	--	--	10,800	8,640
Florida	--	--	159,076	--	490,843	30,989	680,908	32,909,669
Georgia	--	--	1,642,189	--	621,161	6,059,109	8,322,459	437,671,308
Idaho	--	W	W	W	--	W	28,042	263,465
Illinois	--	--	515,319	26,519	W	--	[3]541,838	[3]2,355,435
Indiana	--	--	1,184,278	1,062	--	--	1,185,340	2,340,711
Iowa	--	--	869,676	--	--	--	869,676	2,883,074
Kansas	--	W	1,060,871	--	--	--	[2]1,060,871	[2]2,635,856
Kentucky	W	--	734,090	60,284	--	--	[4]794,374	[4]3,258,996
Louisiana	--	--	415,516	--	--	--	415,516	6,073,392
Maine	--	--	90,030	--	--	--	90,030	163,004
Maryland	W	--	974,831	--	--	--	[4]974,831	[4]2,854,067
Massachusetts	--	--	155,547	--	--	--	155,547	367,070
Michigan	--	--	2,072,107	--	--	--	2,072,107	7,429,990
Minnesota	--	--	135,474	--	--	W	[5]135,474	[5]1,904,984
Mississippi	W	318,078	1,221,404	--	W	--	1,819,891	21,841,270
Missouri	--	--	1,497,161	799,086	--	54,856	2,351,103	20,522,192
Montana	--	385,758	38,178	503	--	--	424,439	11,507,793
Nebraska	--	--	156,144	--	--	--	156,144	453,984
Nevada	--	34,094	W	--	W	W	76,030	1,162,703
New Hampshire	--	--	W	--	--	--	W	W
New Jersey	--	--	51,947	15,044	--	--	66,991	558,956
New Mexico	--	--	74,307	W	--	--	[6]74,307	[6]124,242
New York	W	--	835,581	--	--	--	[4]835,581	[4]3,027,177
North Carolina	--	--	3,308,345	--	--	W	[5]3,308,345	[5]8,385,151
North Dakota	--	--	W	--	--	--	W	W
Ohio	--	--	2,700,331	673,303	--	--	3,373,634	13,494,990
Oklahoma	--	--	948,662	--	--	--	948,662	1,999,129
Oregon	--	--	139,188	--	--	--	139,188	262,740
Pennsylvania	--	--	1,763,164	704,714	--	W	[5]2,467,878	[5]20,099,305
Puerto Rico	--	--	259,722	--	--	--	259,722	555,757
South Carolina	--	--	1,504,744	--	W	766,976	[3]2,271,720	[3]24,491,683
South Dakota	--	--	205,469	--	--	--	205,469	291,506
Tennessee	762,137	W	697,069	--	W	--	1,561,136	26,070,795
Texas	W	65,824	3,610,246	58,398	W	W	3,871,193	21,583,353
Utah	--	8,264	340,653	W	W	--	354,577	1,246,001
Virginia	--	--	1,058,552	--	--	--	1,058,552	3,512,044
Washington	--	--	338,762	W	--	--	[6]338,762	[6]1,549,254
West Virginia	--	--	330,309	W	--	--	[6]330,309	[6]591,668
Wisconsin	--	--	W	--	--	--	W	W
Wyoming	--	3,285,002	186,271	--	--	--	3,471,273	75,096,102
Undistributed	[7]224,423	[7]215,719	[7]241,639	[7]304,276	[7]456,243	[7]191,113	[8]928,466	[8]21,222,590
Total	987,012	4,422,075	37,278,803	2,932,343	1,568,247	7,760,600	54,949,080	846,644,677

W Withheld to avoid disclosing company proprietary data; included with "Undistributed."

[1] Includes Puerto Rico.

[2] Excludes bentonite.

[3] Excludes fuller's earth.

[4] Excludes ball clay.

[5] Excludes kaolin.

[6] Excludes fire clay.

[7] Total of States indicated by symbol W.

[8] Incomplete total; difference included with individual State totals.

Table 4.—Number of mines from which producers sold or used clay in the United States, by State

State	Ball clay		Bentonite		Common clay and shale		Fire clay		Fuller's earth		Kaolin		Total	
	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979
Alabama	--	--	2	1	28	32	6	8	--	--	17	19	53	60
Arizona	1	1	3	3	4	4	1	--	--	--	--	--	9	8
Arkansas	--	--	--	--	13	17	--	--	--	--	2	5	15	22
California	1	1	7	8	46	51	--	--	--	--	6	12	60	72
Colorado	--	--	17	17	29	31	7	11	--	--	--	--	53	59
Connecticut	--	--	--	--	2	3	--	--	--	--	--	--	2	3
Delaware	--	--	--	--	1	1	--	--	--	--	--	--	1	1
Florida	--	--	--	--	2	3	--	--	8	9	2	1	12	13
Georgia	--	--	--	--	19	18	--	--	9	9	52	51	80	78
Idaho	--	--	1	1	2	2	(1)	1	--	--	1	1	4	5
Illinois	--	--	--	--	16	15	3	1	3	3	--	--	22	19
Indiana	--	--	--	--	17	23	3	1	--	--	--	--	20	24
Iowa	--	--	--	--	14	17	--	--	--	--	--	--	14	17
Kansas	--	--	1	1	22	22	--	--	--	--	--	--	23	23
Kentucky	4	4	--	--	9	11	11	16	--	--	--	--	24	31
Louisiana	--	--	--	--	13	13	--	--	--	--	--	--	13	13
Maine	--	--	--	--	6	6	--	--	--	--	--	--	6	6
Maryland	1	1	--	--	9	9	--	--	--	--	--	--	10	10
Massachusetts	--	--	--	--	3	3	--	--	--	--	--	--	3	3
Michigan	--	--	--	--	8	9	--	--	--	--	--	--	8	9
Minnesota	--	--	--	--	3	2	--	--	--	--	1	1	4	3
Mississippi	2	2	4	6	21	22	--	--	2	2	--	--	29	32
Missouri	--	--	--	--	16	17	62	56	1	--	7	10	86	83
Montana	--	--	5	7	10	12	1	1	--	--	--	--	16	20
Nebraska	--	--	--	--	5	6	--	--	--	--	--	--	5	6
Nevada	--	--	5	6	1	2	--	--	--	1	1	1	7	10
New Hampshire	--	--	--	--	1	1	--	--	--	--	--	--	1	1
New Jersey	--	--	--	--	1	1	2	3	--	--	--	--	3	4
New Mexico	--	--	--	--	4	4	2	2	--	--	--	--	6	6
New York	1	1	--	--	11	14	--	--	--	--	--	--	12	15
North Carolina	--	--	--	--	49	49	--	1	--	--	3	2	52	52
North Dakota	--	--	--	--	4	4	--	--	--	--	--	--	4	4
Ohio	--	--	--	--	68	70	24	24	--	--	--	--	92	94
Oklahoma	--	--	--	--	16	18	--	--	--	--	--	--	16	18
Oregon	--	--	--	--	12	13	--	--	--	--	--	--	12	13
Pennsylvania	--	--	--	--	42	51	33	45	--	--	2	2	77	98
Puerto Rico	--	--	--	--	2	2	--	--	--	--	--	--	2	2
South Carolina	--	--	--	--	32	36	--	--	1	1	17	20	50	57
South Dakota	--	--	2	2	3	3	--	--	--	--	--	--	5	5
Tennessee	25	26	--	--	15	17	--	--	1	1	--	--	41	44
Texas	2	4	4	10	87	84	5	2	3	3	1	2	102	105
Utah	--	--	2	3	8	8	1	5	1	1	--	--	12	17
Virginia	--	--	--	--	15	15	--	--	--	--	--	--	15	15
Washington	--	--	--	--	12	12	1	2	--	--	--	--	13	14
West Virginia	--	--	--	--	4	4	2	2	--	--	--	--	6	6
Wisconsin	--	--	--	--	1	1	--	--	--	--	--	--	1	1
Wyoming	--	--	70	81	4	4	--	--	--	--	--	--	74	85
Total	37	40	123	146	710	762	164	181	29	30	112	127	1,175	1,286

[1] Included with common clay and shale.

DOMESTIC PRODUCTION, PRICES, AND FOREIGN TRADE, BY TYPE OF CLAY

KAOLIN

Domestic production of kaolin in 1979 increased 11%, and the value increased 26%. The average unit value for all grades of kaolin in 1979 was $59.57 per ton, $6.83 higher than in 1978. Kaolin was produced at mines in 13 States. Two States, Georgia (78%) and South Carolina (10%), accounted for 88% of the total U.S. production in 1979. Alabama ranked third; Arkansas, fourth; and North Carolina, fifth. Output in 1979 increased in Alabama, Arkansas, Florida, Georgia, Idaho, Minnesota, Missouri, North Carolina, and Pennsylvania, but declined in California, Nevada, South Carolina, and Texas.

Kaolin is defined as a white, claylike material approximating the mineral kaolinite. It has a specific gravity of 2.6 and a fusion point of 1,785°C. The other kaolin-group minerals, such as halloysite and dickite, are encompassed.

All Georgia water-washed kaolin producers either announced planned increases in production or were presently increasing production during 1978 and 1979. Anglo-American Clays Corp. completed its new calciner-spray dryer facility in Sandersville, Ga. Engelhard Minerals and Chemicals Corp. announced a major expansion of its plant near McIntyre. This expansion, scheduled for completion in early 1981 and including new calciners and filters, was to increase the availability of its filler, coater, and extender lines. Freeport Kaolin Co. commissioned a $3.5 million, 14-cubic-yard electric dragline at its new Scott mine in Sandersville in 1978, and in 1979 scheduled a 3-year, $22 million enlargement designed to add 30% more capacity at its Gordon facility. Georgia Kaolin Co. completed one phase of its planned expansion at Dry Branch, with the other phase still actively underway.

Nord Kaolin Co. (NK) was installing a new spray dryer and planned to eventually double its Jeffersonville (Twiggs County) plant's (acquired from Cyprus Mines Corp. in 1977) capacity to 300,000 tons per year. The NK expansion, scheduled over a 4-year period, was to include a new magnetic separator. This now brings the number of large domestic (over 84-inch) high-intensity magnetic separators (HIMS), either active or planned, to 12, with many other smaller throughput units in service. Magnetic separators are also in service in England and the Federal Republic of Germany. The HIMS is apparently an established unit in the worldwide wet processing of kaolin. In another move, Nord Resources Corp., an 80% owner of NK, was negotiating to acquire Howard Paper Mills, Inc. Other companies with expansion projects underway or being planned were Thiele Kaolin Co. at its Sandersville and Wrens plants (a total of 30%) and J. M. Huber Corp. at its Wrens and Edisto, S.C., facilities.

In other kaolin-related actions during 1979, NL Clays Corp., commonly known as Edgar Plastic Kaolin Corp. (EPK), a subsidiary of NL Industries, Inc., was sold to Feldspar Corp., itself a subsidiary of Pacific Tin Consolidated Corp. Cyprus Mines Corp. was merged into Standard Oil Co. (Indiana). The Industrial Minerals Division of Cyprus (including talc and ball clay operations) also reported plans to add new capacity to its Sandersville airfloat facility. R. T. Vanderbilt Co. began expanding its Dixie Clay divisional operations at Bath, S.C. It was estimated that the output of Dixie Clay's other air-floated kaolin products will be increased by at least 35%. Interpace Corp., a calcined kaolin grog producer and refractories manufacturer located near Ione, Calif., figured prominantly in acquisition news. The NL Industries, Inc. refractory interests sold to Didier-Werke AG, of Wiesbaden, the Federal Republic of Germany for approximately $32 million, included the Taylor Refractories Division, Cincinnati, Ohio, and Wilson-Snead Division, Eufala, Ala. Wilson-Snead supplies a range of bauxitic and kaolinitic clay mixtures for Taylor's use in manufacturing clay-based, high alumina refractories.

Exports of kaolin, as reported by the U.S. Department of Commerce, increased from 1.174 million tons valued at $95.4 million in 1978 to 1.583 million tons valued at $125.9 million in 1979. The tonnage of kaolin exported in 1979 increased 35%, while the value rose 32% over that shipped in 1978. The unit value of kaolin exported was attributed to both the greater percentage of the higher quality paper-coating grades shipped and higher prices.

Kaolin, including calcined, was exported to 52 countries. The major recipients were Japan, 29%; the Federal Republic of Germany, 19%; Canada, 14%; Italy, 12%; Mexico, 5%; and the remaining countries, 21%. Of those countries listed in 1979, exports to 24 countries increased, and to 7 countries, decreased. Three countries were added that were not listed in 1978; four countries listed in 1978 do not appear in 1979. Kaolin producers reported the end uses for their exports as follows: Paper coating, 42%; refractories, 20%, foundry sand, 3%; rubber, 3%; and others, including adhesives, ceramics, paint, paper filling, and plastics, 32%.

Kaolin imports in 1979 increased from 12,795 tons valued at $854,000 in 1978 to 31,456 tons valued at $1.886 million. The United Kingdom supplied 96%; Canada, 3%; and three other countries, 1%.

Kaolin prices quoted in the trade journals in 1979, with the exception of the calcined and delaminated grade, remained unchanged from 1978. Chemical Marketing Reporter, December 31, 1979, quoted prices as follows:

Waterwashed, fully calcined, bags, carload lots, f.o.b. Georgia, per ton	$175.00-$208.00
Paper-grade, uncalcined, bulk, carload lots, f.o.b. Georgia, per ton:	
No. 1 coating	76.00
No. 2 coating	61.00
No. 3 coating	60.00
No. 4 coating	57.00
Filler, general purpose, same basis, per ton	43.00
Delaminated, waterwashed, uncalcined, paint-grade, 1-micrometer average, same basis, per ton	125.00- 163.00
Dry-ground, air-floated, soft, same basis, per ton	25.00
National Formulary, powder, colloidal, bacteria controlled, 50-pound bags, 5,000-pound lots, per pound	.24

The average unit value reported by domestic kaolin producers was $59.57 per ton, an increase of $6.83 above the 1978 value.

Table 5.—Kaolin sold or used by producers in the United States, by State

State	1978		1979	
	Short tons	Value	Short tons	Value
Alabama	264,719	$11,534,369	465,510	$20,720,542
Arkansas	59,365	3,561,900	132,015	6,340,345
California	63,725	1,445,071	60,032	2,086,627
Florida	28,755	W	30,989	W
Georgia	5,531,835	325,266,250	6,059,109	404,185,621
Missouri	51,412	872,974	54,856	978,067
South Carolina	784,638	18,149,802	766,976	20,342,400
Other States[1]	188,865	6,952,042	191,113	7,666,486
Total	6,973,314	367,782,408	7,760,600	462,320,088

W Withheld to avoid disclosing company proprietary data; included with "Other States."

[1] Includes Idaho, Minnesota, Nevada, North Carolina, Pennsylvania, Texas, and data indicated by symbol W.

Table 6.—Kaolin sold or used by producers in the United States, by kind

Kind	1978		1979	
	Short tons	Value	Short tons	Value
Airfloat	1,203,616	$39,806,219	1,273,856	$40,630,228
Calcined[1]	1,189,561	93,158,889	1,409,019	115,702,435
Delaminated	398,343	31,954,998	358,293	31,891,253
Unprocessed	803,358	7,998,362	973,788	15,283,115
Waterwashed	3,378,436	194,863,940	3,745,644	258,813,057
Total	6,973,314	367,782,408	7,760,600	462,320,088

[1] Includes both low-temperature filler and high-temperature refractory grades.

Table 7.—Calcined kaolin sold or used by producers in the United States, by kind

State	High temperature		Low temperature	
	Short tons	Value	Short tons	Value
1978				
Georgia	630,599	$40,836,593	227,713	$35,645,002
Other States	[1]276,835	[1]13,419,331	[2]54,414	[2]3,257,963
Total	907,434	54,255,924	282,127	38,902,965
1979				
Georgia	676,307	47,835,984	244,654	44,089,845
Other States	[1]431,702	[1]20,442,791	[2]56,356	[2]3,333,815
Total	1,108,009	68,278,775	301,010	47,423,660

[1] Includes Alabama, Arkansas, and California.

[2] Includes Idaho, Pennsylvania, and Texas.

Table 8.—Georgia kaolin sold or used by producers, by kind

Kind	1978		1979	
	Short tons	Value	Short tons	Value
Airfloat	883,357	$21,893,179	717,449	$20,483,169
Calcined[1]	858,312	76,481,595	920,961	91,925,829
Delaminated	398,343	31,954,998	358,293	31,891,253
Unprocessed	317,975	1,339,717	359,875	2,483,198
Waterwashed	3,073,848	193,596,761	3,702,531	257,402,172
Total	5,531,835	325,266,250	6,059,109	404,185,621

[1] Includes both low-temperature filler and high-temperature refractory grades.

Table 9.—Georgia kaolin sold or used by producers, by kind and use

(Short tons)

Use	1978				1979			
	Airfloat	Un-processed	Water-washed[1]	Total	Airfloat	Un-processed	Water-washed[1]	Total
Domestic:								
Adhesives	39,053	--	17,155	56,208	36,553	--	8,191	44,744
Alum (aluminum sulfate) and other chemicals	--	216,860	23,150	240,010	200	245,004	8,181	253,385
Animal feed	W	--	--	W	W	--	--	W
Asphalt tile and linoleum	37,004	2,980	--	39,984	38,871	4,670	--	43,541
Catalysts (oil refining)	W	--	W	50,401	W	W	W	62,171
China and dinnerware; crockery and earthenware	23,717	3,486	20,287	47,490	15,707	3,398	18,830	37,935
Electrical porcelain	W	--	W	15,569	16,894	--	--	16,894
Face brick	W	32,400	W	32,506	267	18,500	55	18,822
Fiberglass and mineral wool	101,871	--	--	101,871	109,807	--	2,393	112,200
Firebrick, block, shapes	1,083	14,123	--	15,206	536	11,112	--	11,648
Floor and wall tile, ceramic	W	--	W	21,472	W	--	W	13,248
Flue linings and high-alumina brick	41,687	14,994	--	56,681	41,195	13,043	--	54,238
Foundry sand	2,489	9,078	--	11,567	770	--	--	770
Glazes, glass, enamels, hobby ceramics	W	--	--	W	W	--	--	W
Grogs and crudes, refractory	22,333	318,042	--	340,375	18,533	400,270	17	418,820
Ink	--	--	W	745	W	--	--	W
Kiln furniture, mortar, cement	W	W	--	18,316	--	W	W	34,681
Medical, pharmaceutical, cosmetic	W	--	W	1,091	W	--	W	2,036
Paint	--	--	119,058	119,058	10,651	--	109,273	119,924
Paper coating	167,004	--	2,068,225	2,235,229	61,872	--	2,212,338	2,274,210
Paper filling	106,119	--	654,952	761,071	86,853	--	771,452	858,305
Plastics	3,596	--	58,423	62,019	2,436	--	53,487	55,923
Pottery	4,777	--	--	4,777	7,988	15,284	--	23,272
Roofing granules	W	W	--	26,877	W	--	W	12,646
Roofing and structural tile	1,526	--	--	1,526	--	4,995	--	4,995
Rubber	65,321	--	10,562	75,883	77,303	--	11,615	88,918
Sanitary ware	103,578	W	W	103,632	117,074	W	W	128,400
Miscellaneous airfloat:								
Fertilizer, oil and grease absorbents, pet waste absorbents, pesticides and related products, unknown	15,219	--	--	15,219	5,356	--	--	5,356

See footnotes at end of table.

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Table 9.—Georgia kaolin sold or used by producers, by kind and use —Continued

(Short tons)

Use	1978				1979			
	Airfloat	Un-processed	Water-washed[1]	Total	Airfloat	Un-processed	Water-washed[1]	Total
Domestic: —Continued								
Miscellaneous, unprocessed:								
Gypsum products, common brick (1979), flower pots (1979), sewer pipe (1979), quarry tile (1979), portland cement (1979)	--	33,176	--	33,176	--	23,891	--	23,891
Miscellaneous, waterwashed:								
Gypsum products, pesticides and related products (1979), waterproofing and sealing, unknown, other	--	--	86,964	86,964	--	--	65,087	65,087
Undistributed	132,164	102,739	85,446	[2]185,718	49,424	92,563	83,142	[2]89,021
Total	868,541	747,878	3,144,222	4,760,641	698,290	832,730	3,344,061	4,875,081
Exports:								
Foundry sand	--	113,873	--	113,873	--	--	--	--
Paint	1,295	--	23,348	24,643	17,999	--	12,151	30,150
Paper coating	--	--	523,629	523,629	--	--	580,435	580,435
Paper filling	3,164	--	46,900	50,064	1,082	--	52,859	53,941
Plastics	--	--	18,401	18,401	--	--	23,324	23,324
Refractories	8,798	--	1,948	10,746	--	276,037	--	276,037
Rubber	7	--	740	747	78	--	843	921
Undistributed	1,552	--	27,539	29,091	--	172,069	47,151	219,220
Total	14,816	113,873	642,505	771,194	19,159	448,106	716,763	1,184,028
Grand total	883,357	861,751	3,786,727	5,531,835	717,449	1,280,836	4,060,824	6,059,109

W Withheld to avoid disclosing company proprietary data; included with "Undistributed."

[1] Includes calcined and delaminated.

[2] Incomplete total; difference included in totals for specific uses.

Table 10.—South Carolina kaolin sold or used by producers, by kind

Kind	1978		1979	
	Short tons	Value	Short tons	Value
Airfloat	531,163	$16,481,367	522,262	$18,453,671
Unprocessed	253,475	1,668,435	244,714	1,888,729
Total	784,638	18,149,802	766,976	20,342,400

Table 11.—South Carolina kaolin sold or used by producers, by kind and use

(Short tons)

Kind and use	1978	1979
Airfloat:		
Adhesives	18,020	19,937
Animal feed and pet waste absorbent	1,941	2,595
Ceramics[1]	31,998	20,912
Fertilizers	17,674	16,564
Fiberglass	91,631	96,256
Paint	934	747
Paper coating and filling	5,120	4,519
Pesticides and related products	18,259	23,059
Plastics	8,190	9,310
Rubber	255,990	244,098
Other refractories[2]	8,509	8,514
Other uses[3]	6,284	4,233
Exports[4]	66,613	71,518
Total	531,163	522,262
Unprocessed: Face brick; firebrick, block and shapes; high-alumina refractories (1978); miscellaneous	253,475	244,714
Grand total	784,638	766,976

[1] Includes floor and wall tile, pottery, roofing granules, sanitary ware, and glazes, glass, and enamels.

[2] Includes high-alumina refractories (1978), refractory mortar and cement, and refractory grogs and crudes.

[3] Includes common brick (1978), crockery and other earthenware, structural tile (1978), roofing tile, ink, and miscellaneous.

[4] Includes ceramics, fertilizers, paper filling, plastics, rubber, and miscellaneous.

Table 12.—Kaolin sold or used by producers in the United States, by kind and use

(Short tons)

Use	1978				1979			
	Airfloat	Un-processed[1]	Water-washed[2]	Total	Airfloat	Un-processed[1]	Water-washed[2]	Total
Domestic:								
Adhesives	57,073	W	17,583	W	56,490	W	8,622	W
Alum (aluminum sulfate) and other chemicals	--	270,912	23,150	294,062	425	302,449	46,181	349,055
Animal feed	3,537	262	5,918	9,717	7,532	108	5,413	13,053
Brick, common and face	1,404	350,531	34	351,969	982	356,286	55	357,323
Catalysts (oil and gas refining)	3,286	--	47,115	50,401	W	W	W	62,171
Cement, portland	--	W	W	29,067	--	W	W	12,797
Ceramic (hobby and artware)	--	--	--	--	W	--	--	W
China and dinnerware	8,650	6,126	17,980	32,756	12,024	5,988	18,781	36,793
Crockery and other earthenware	19,783	700	2,307	22,790	12,063	737	49	12,849
Electrical porcelain	21,644	3,960	2,238	27,842	25,797	3,884	--	29,681
Fertilizers [3]	18,042	662	11,873	30,577	16,522	529	10,212	27,263
Fiberglass; mineral wool and other insulation	193,502	--	7,538	201,040	207,222	--	9,291	216,513
Firebrick, block, shapes	2,227	278,058	--	280,285	536	388,737	--	389,273
Floor and wall tile, ceramic	22,528	4,890	9,605	36,523	22,930	4,390	W	27,320
Flue linings and high-alumina brick	41,687	14,994	--	56,681	41,195	13,043	--	54,238
Foundry sand	2,863	--	--	2,863	770	--	--	770
Glazes, glass, enamels	760	200	3,824	4,784	373	210	3,018	3,601
Grogs and crudes, refractory	27,800	458,640	--	486,440	24,270	546,037	17	570,324
Gypsum products	1,786	647	3,906	6,339	963	662	4,957	6,582
Ink	760	--	745	1,505	W	--	--	W
Kiln furniture	2,838	--	--	2,838	2,293	--	--	2,293
Linoleum and asphalt tile	37,004	2,980	--	39,984	38,871	4,670	--	43,541
Medical, pharmaceutical, cosmetic	--	--	1,091	1,091	W	--	W	2,309
Mortar and cement, refractory	1,315	18,785	--	20,100	W	35,621	W	36,715
Paint	934	--	166,366	167,300	11,398	--	157,725	169,123
Paper coating	38,598	1,574	2,198,225	2,238,397	63,589	648	2,212,338	2,276,575
Paper filling	68,645	--	695,952	764,597	89,655	--	771,452	861,107
Pesticides and related products	20,092	12,524	436	33,052	45,019	634	403	46,056
Plastics	11,786	--	58,423	70,209	11,746	--	53,487	65,233
Pottery	9,275	3,960	--	13,235	12,821	19,903	--	32,724
Roofing granules	25,882	15,400	--	41,282	12,980	W	W	14,219
Roofing tile and structural tile	2,358	--	--	2,358	650	4,915	--	5,645

Rubber	321,311	--	17,353	338,664	321,480	2,450	18,082	342,012
Sanitary ware	117,749	--	3,422	121,171	132,215	W	14,774	146,989
Waterproofing and sealing	--	--	122	122	--	--	706	706
Miscellaneous	38,242	29,282	120,345	[4]233,408	8,594	121,484	47,099	[4]162,599
Total	1,123,361	1,474,587	3,415,501	6,013,449	1,181,405	1,813,385	3,382,662	6,377,452
Exports:								
Ceramics	1,832	--	900	2,732	2,530	--	4,512	7,042
Foundry sand; grogs, crudes, other refractories	8,798	236,205	1,948	246,951	310	320,097	--	320,407
Paint	1,296	--	23,348	24,643	17,999	--	12,151	30,150
Paper coating	--	--	523,629	523,629	--	--	580,435	580,435
Paper filling	5,111	--	46,900	52,011	3,006	--	52,859	55,865
Plastics	17	--	18,401	18,418	--	--	23,324	23,324
Rubber	43,914	--	740	44,654	47,354	--	843	48,197
Other	19,288	--	27,539	46,827	21,252	249,325	47,151	317,728
Total	80,255	236,205	643,405	959,865	92,451	569,422	721,275	1,383,148
Grand total	1,203,616	1,710,792	4,058,906	6,973,314	1,273,856	2,382,807	4,103,937	7,760,600

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous."

[1] Includes high-temperature calcined.

[2] Includes low-temperature calcined and delaminated.

[3] Includes soil conditioners and mulches.

[4] Incomplete total; remainder included with totals for specific uses.

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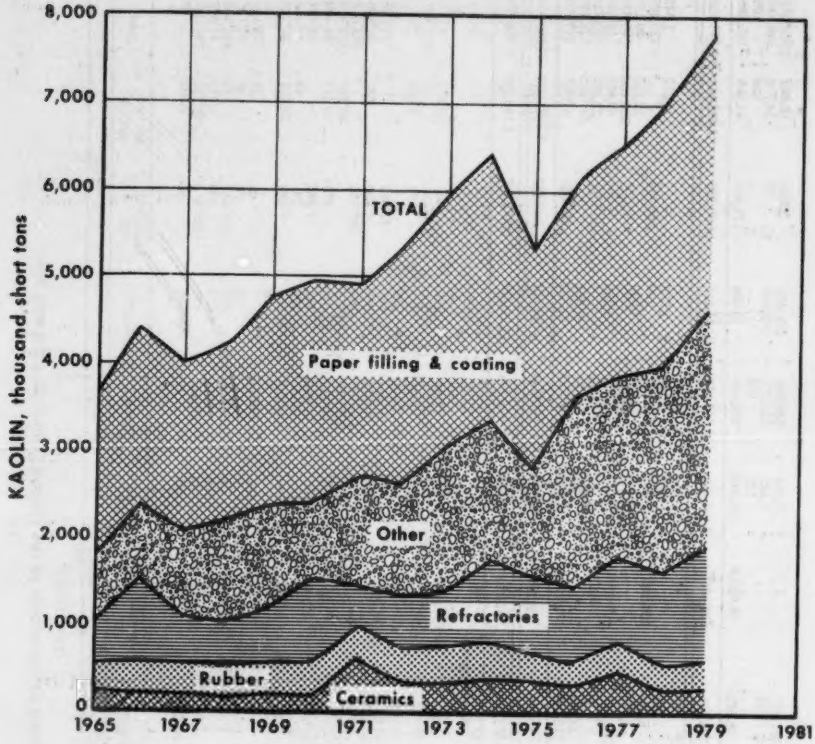

Figure 1.—Kaolin sold or used by domestic producers for specified uses.

BALL CLAY

Production and value reported for domestically mined ball clay in 1979 increased 5% and 21%, respectively. Tennessee provided 77% of the Nation's output, followed in order by Mississippi, Kentucky, Texas, Maryland, California, New York,[3] and Arizona. Production in Tennessee and Texas increased over that reported in 1978, but production in Kentucky, Maryland, and New York decreased.

Ball clay is defined as a plastic, white-firing clay used principally for bonding in ceramic ware. The clays are of sedimentary origin and consist mainly of the clay mineral kaolinite and sericite micas.

During 1979, Southern Clay Products, Inc., a Texas ball clay, bentonite, and talc producer, was acquired by the English China Clay Group (ECC) of Cornwall, England. ECC's two other U.S. subsidiaries are Anglo-American Clays Corp., a Georgia kaolin producer, and Gonzales Clay Corp., a Texas bentonite producer. A strike of a major ball clay producer created a tight supply situation during its duration.

The average unit value for ball clay reported by domestic producers rose in 1979 to $26.46 per ton, an increase of $3.44 per ton. Chemical Marketing Reporter, December 31, 1979, listed ball clay prices unchanged from 1978, as follows:

Domestic, air-floated, bags, carload lots, Tennessee, per ton	$18.00-$22.00
Domestic, crushed, moisture-repellent, bulk, carload lots, Tennessee, per ton	8.00- 11.25
Imported, air-floated, bags, carload lots, Atlantic ports, per ton	70.00
Imported, lump, bulk, Great Lakes, per ton	40.50

Ball clay exports in 1979 amounted to 169,000 short tons valued at $5.3 million, compared with 144,000 tons worth $4.3 million in 1978. Tonnage and value increased 17% and 23%, respectively, compared with those of 1978. Unit value increased $1.44 per ton. These shipments were made to 25 countries. The major recipients were Mexico, 58%, and Canada, 30%.

Ball clay imports, from Canada and the United Kingdom, increased in quantity but decreased in value from 7,098 tons valued at $418,000 in 1978 to 11,239 tons valued at $666,000 in 1979.

Table 13.—Ball clay sold or used by producers in the United States, by type and State

Year and State	Airfloat		Unprocessed		Total	
	Short tons	Value	Short tons	Value	Short tons	Value
1978						
Tennessee	416,067	$10,004,341	246,168	$4,834,216	662,235	$14,838,557
Other States	[1]164,700	[1]4,867,909	[2]109,316	[2]1,843,093	274,016	6,711,002
Total	580,767	14,872,250	355,484	6,677,309	936,251	21,549,559
1979						
Tennessee	504,679	14,662,462	257,458	5,000,576	762,137	19,663,038
Other States	[1]149,588	[1]4,881,138	[2]75,287	[2]1,575,789	224,875	6,456,927
Total	654,267	19,543,600	332,745	6,576,365	987,012	26,119,965

[1] Includes Kentucky, Maryland, Mississippi, and Texas.
[2] Includes Arizona, California, Kentucky, Mississippi, New York, and Texas.

Table 14.—Ball clay sold or used by producers in the United States, by kind and use

(Short tons)

Use	1978			1979		
	Air-float	Un-processed	Total	Air-float	Un-processed	Total
Adhesives	513	--	513	549	--	549
Animal feed	W	--	W	W	--	W
Brick, face	--	W	W	--	W	W
China and dinnerware	42,202	--	42,202	44,476	--	44,476
Crockery and other earthenware	16,748	--	16,748	22,506	--	22,506
Drilling mud	W	--	W	W	--	W
Electrical porcelain	29,519	6,810	36,329	28,250	6,810	35,060
Fiberglass and catalysts (oil refining)	65,914	--	65,914	71,213	--	71,213
Firebrick, block, shapes	W	W	8,619	W	W	8,471
Glasses, glass, enamels	W	W	1,760	W	W	1,644
Grogs and crudes, high-alumina; mortar and cement refractories	77,066	5,800	82,866	86,249	2,521	88,770
Kiln furniture	W	W	6,246	W	W	2,187
Paper coating and filling	10,965	--	10,965	13,082	--	13,082
Pesticides and related products	834	--	834	732	--	732
Pottery	93,996	169,513	263,509	105,559	141,502	247,061
Rubber	718	--	718	W	--	W
Sanitary ware	54,168	87,184	141,352	63,632	87,973	151,605
Tile:						
Floor and wall	89,311	24,433	113,744	84,406	29,034	113,440
Other	3,993	--	3,993	6,042	--	6,042
Miscellaneous	40,372	16,634	40,381	54,786	15,039	57,514
Exports	54,448	45,110	99,558	72,785	49,875	122,660
Total	580,767	355,484	936,251	654,267	332,745	987,012

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous."

FIRE CLAY

Fire clay sold or used by domestic producers in 1979 was reported at 2,932,343 tons valued at $47.2 million. Fire clay is defined as detrital material, either plastic or rocklike, containing low percentages of iron oxide, lime, magnesia, and alkalies to enable the material to withstand temperatures of 1,500° C or higher. Fire clay is basically kaolinite but usually contains other materials such as diaspore, ball clay, bauxite clay, and shale. Fire clays commonly occur as underclay below coal seams and are generally used for refractories. Some fire clay was previously reported in other end uses.

In 1979, Harbison-Walker Refractories Div. of Dresser Industries, Inc. completed a multimillion-dollar expansion of its Vandalia, Mo., fire clay and high-alumina refractory manufacturing operation.

Fire clay production was reported in 1979 from mines in 16 States. The first five States in rank—Missouri, Pennsylvania, Ohio, West Virginia, and Alabama—accounted for 92% of the total domestic output.

Exports of fire clay decreased from 236,000 tons worth $12.0 million in 1978 to 224,000 tons valued at $13.5 million in 1979. Fire clay exports decreased 5% in tonnage and increased 13% in value. The price of exported fire clay decreased by $9.57 to $60.50 per ton, indicating a larger percentage of standard quality shipped.

Fire clay was exported to 25 countries in 1979, with the Federal Republic of Germany, Canada, and Mexico receiving 27%, 20%, and 19%, respectively. No imports of fire clay were reported during 1979.

There are no price quotations in domestic journals for fire clay, but the per-ton value reported by producers ranged from $3.81 to $19.75. The reported average unit value for fire clay produced in the United States increased 18% from $13.62 per ton in 1978 to $16.09 in 1979.

Table 15.—Fire clay sold or used by producers in the United States, by State[1]

State	1978		1979	
	Short tons	Value	Short tons	Value
Alabama	422,557	$5,041,043	247,257	$4,480,804
Colorado	47,040	292,191	41,897	259,715
Illinois	42,790	435,071	26,519	249,279
Indiana	985	14,841	1,062	15,491
Kentucky	42,817	312,510	60,284	476,735
Missouri	772,833	12,190,094	799,086	15,193,699
Montana	706	3,530	503	2,515
New Jersey	15,847	114,673	15,044	286,234
Ohio	805,647	7,321,766	673,303	6,290,961
Pennsylvania	633,763	11,383,649	704,714	13,921,224
Texas	50,287	273,494	58,398	724,484
Utah	W	W	W	W
Other States[2]	290,681	5,178,570	304,276	5,277,852
Total	3,125,953	42,561,432	2,932,343	47,178,993

W Withheld to avoid disclosing company proprietary data; included with "Other States."

[1] Refractory uses only.

[2] Includes Arizona (1978), Idaho, New Mexico, Washington, West Virginia, and data indicated by symbol W.

BENTONITE

Bentonite production in 1979 decreased 1% in tonnage and increased 20% in value over that of 1978. A general decrease was noted in domestic consumption, particularly in foundry sand and animal feed; waterproofing and sealing showed a slight increase. A decrease was also noted in bentonite exports.

Bentonite was produced in 13 States in 1979. Increased bentonite production was reported for Colorado, Idaho, Montana, Nevada, Tennessee, Texas, and Utah. Production decreased in Alabama, Arizona, California, Mississippi, and Wyoming, and remained the same in Kansas. South Dakota reported no production.

Generally, the high-swelling or sodium bentonites are produced chiefly in Wyoming, Montana, and California. The calcium or low-swelling bentonites are produced in the other States.

During 1978 and 1979, all the major western and southern bentonite producers either announced planned expansion or had expansions underway. With the successful conversion to coal from oil and gas firing in dryers, the industry was exploring the practicality of augmenting coal with wood chips as a fuel.

In other events in 1979, NL Industries was expanding its NL Chemicals' Bentone plant in Charleston, W. Va., to double current production. The plant expansion was scheduled for completion in early 1981. Bentone, an organic derivative of hectorite clay (hydrous lithium magnesium aluminum silicate) is used as a gelling and pigment-suspending agent in the paint, ink, plastics, and cosmetics industries. The company has additional Bentone production facilities in St. Louis, Mo.; Newberry, Calif.; Livingston, Scotland; and in Nordenham, the Federal Republic of Germany. Gulf Resources and Chemical Corp. exercised its options to acquire Industrial Mineral Ventures Inc. (IMV) which is engaged in mining and processing specialty clays and drilling muds. IMV reportedly has large reserves of bentonite, sepiolite, saponite, and hectorite clays, and calcium carbonate on the California-Nevada border, approximately 80 miles northwest of Las Vegas. These minerals have applications in drilling muds, paints, paper coating, and detergents.

On December 31, 1979, Chemical Marketing Reporter quoted bentonite prices as rising. Domestic material, 200 mesh, bags, carload lots, f.o.b. mines, was priced from $28 to $30 per ton; and imported Italian, white, high-gel material, bags, 5-ton lots, ex-warehouse was not listed. The average unit value reported by domestic producers for bentonite sold or used in 1979 was $24.09, an increase of $4.30 from the $19.79 average of 1978. Per-ton values reported in the various producing States ranged from $5.86 to $67.91, but the average value reported by the larger producers was near the Montana average figure of $29.46.

Bentonite exports in 1979 increased from 723,000 tons in 1978 to 853,000 tons; value increased from $43.3 million in 1978 to $55.3 million in 1979. This increase in value was the result of an increase in the unit value of exported bentonite from $59.82 per ton in 1978 to $64.77 per ton in 1979. This increase in per-ton value of exports was attributed to the return to a larger percentage of the

Table 16.—Bentonite sold or used by producers in the United States, by type and State

State	Nonswelling		Swelling		Total	
	Short tons	Value	Short tons	Value	Short tons	Value
1978						
Arizona	W	W	W	W	35,802	$476,083
California	13,750	$378,125	73,975	$3,211,697	87,725	3,589,822
Colorado	1,000	12,600	W	W	W	W
Mississippi	358,265	7,741,896	--	--	358,265	7,741,896
Montana	--	--	181,257	3,571,199	181,257	3,571,199
Nevada	5,400	88,506	3,356	55,520	8,756	144,026
Texas	55,419	1,100,708	--	--	55,419	1,100,708
Utah	920	16,560	6,000	24,000	6,920	40,560
Wyoming	--	--	3,452,386	66,362,907	3,452,386	66,362,907
Other States	[1]198,446	[1]3,633,289	[2]117,431	[2]2,228,730	[3]281,075	[3]5,398,586
Total	633,200	12,971,684	3,834,405	75,454,053	4,467,605	88,425,737
1979						
Arizona	W	W	W	W	28,176	330,564
California	13,550	391,053	67,610	4,752,171	81,160	5,143,224
Colorado	1,000	14,100	W	W	W	W
Mississippi	318,078	7,127,584	--	--	318,078	7,127,584
Montana	--	--	385,758	11,362,748	385,758	11,362,748
Nevada	--	--	34,094	612,919	34,094	612,919
Texas	65,824	3,241,749	--	--	65,824	3,241,749
Utah	840	16,800	7,424	31,666	8,264	48,466
Wyoming	--	--	3,285,002	74,405,909	3,285,002	74,405,909
Other States	[1]176,200	[1]3,744,269	[2]66,695	[2]827,582	[3]215,719	[3]4,255,387
Total	575,492	14,535,555	3,846,583	91,992,995	4,422,075	106,528,550

W Withheld to avoid disclosing company proprietary data; included with "Other States."

[1] Includes Alabama, Idaho, and data indicated by symbol W.

[2] Includes Idaho (1979), Kansas, South Dakota (1978), Tennessee, and data indicated by symbol W.

[3] Incomplete total; difference included with totals for specific States.

higher cost drilling muds and foundry sand grades shipped. Domestic bentonite producers were facing increased competition in foreign markets. Bentonite from the Greek Island of Milos was being blended with the U.S. clay for pelletizing Canadian taconite ores on a large scale.

Bentonite was exported to 56 countries in 1979. The major recipients were Canada, 43%; Australia, 9%; the Netherlands and Japan, 8% each; the United Kingdom, 5%; and others, 27%. Domestic bentonite producers reported that the end uses of their exports were foundry sand, 38%; drilling mud, 26%; iron ore pelletizing, 24%; and others (including pet waste absorbent, waterproofing and sealing, and fertilizers), 12%.

Bentonite imports in 1979, including chemically activated material, totaled 2,577 tons valued at $800,000, compared with 2,641 tons valued at $481,000 in 1978. The 2,495 tons of chemically activated bentonite was imported from four countries, with Canada supplying 44%; the Federal Republic of Germany, 29%; Mexico, 26%; and the United Kingdom, the remaining 1%.

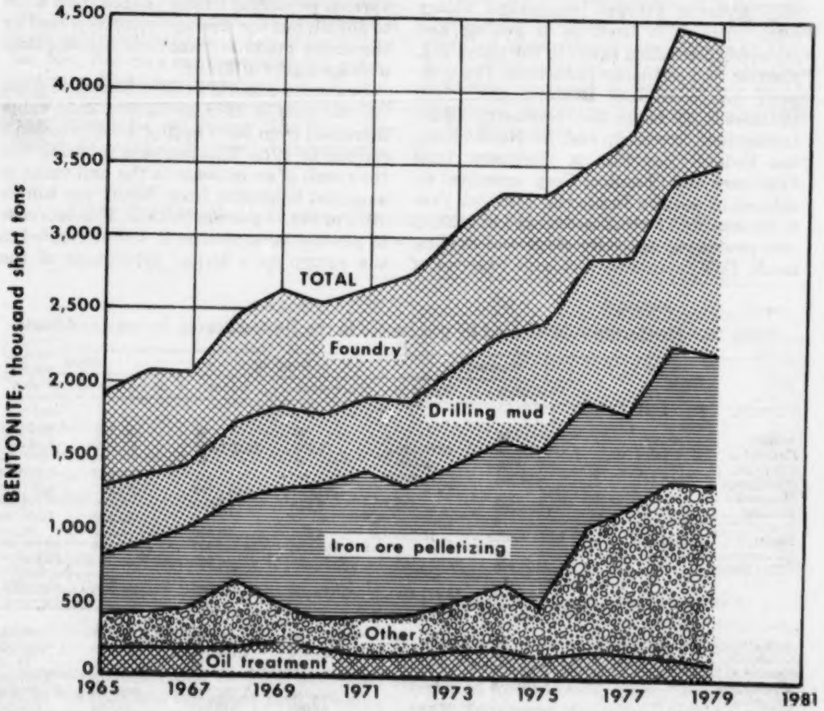

Figure 2.—Bentonite sold or used by domestic producers for specified uses.

Table 17.—Bentonite sold or used by producers in the United States, by type and use

(Short tons)

Use	1978			1979		
	Non-swelling	Swelling	Total	Non-swelling	Swelling	Total
Domestic:						
Adhesives	W	2,747	2,747	W	1,219	1,219
Animal feed	63,109	148,161	211,270	70,234	113,813	184,047
Brick, face	W	--	W	W	--	W
Catalysts (oil refining)	16,843	--	16,843	4,511	--	4,511
Cement, portland	--	W	W	--	W	W
Drilling mud	412	1,143,635	1,144,047	14,658	1,261,477	1,276,135
Fertilizers	2,420	17	2,437	4,764	--	4,764
Filtering, clarifying, decolorizing:						
Animal oils and mineral oils and greases	83,749	9,379	93,128	91,044	6,784	97,828
Vegetable oils	63,184	--	63,184	18,508	--	18,508
Foundry sand	337,889	697,939	1,035,828	300,576	595,697	896,273
Glazes, glass, enamels	W	W	W	--	W	W
Gypsum products	--	W	W	--	W	W
Medical, pharmaceutical, cosmetic	50	1,232	1,282	--	3,295	3,295
Paint	213	26,767	26,980	--	13,905	13,905
Pelletizing (iron ore)	183	939,274	939,457	13,504	888,204	901,708
Pesticides and related products	1,496	3,259	4,755	1,403	2,787	4,190
Pet waste absorbent	--	W	W	--	W	W
Waterproofing and sealing	2,952	71,447	74,399	34,372	41,321	75,693
Miscellaneous	42,040	202,364	[1]244,404	423	233,481	[1]233,904
Total	614,540	3,246,221	3,860,761	553,997	3,161,983	3,715,980
Exports:						
Drilling mud	--	171,388	171,388	--	180,067	180,067
Foundry sand	16,998	222,202	239,200	16,964	250,066	267,030
Pelletizing (iron ore)	--	164,086	164,086	--	172,515	172,515
Other	1,662	30,508	32,170	4,531	81,952	86,483
Total	18,660	588,184	606,844	21,495	684,600	706,095
Grand total	633,200	3,834,405	4,467,605	575,492	3,846,583	4,422,075

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous."

[1] Incomplete total; difference included with total for each specific use.

FULLER'S EARTH

Production of fuller's earth in 1979 increased 3% in quantity and 11% in value. The unit value assigned by domestic producers increased $4.13 in 1979 to $52.14 per ton. This increase in value was due to large increases in unit value by Florida, Georgia, Illinois, Mississippi, and Tennessee producers.

Fuller's earth production was reported from operations in nine States. The two top producing States, Georgia (40%) and Florida (31%), accounted for 71% of the domestic production. The other seven States accounted for the remaining 29%. All States except South Carolina, Tennessee, and Utah showed slight gains in production. Missouri reported production for 1978 but not 1979.

Fuller's earth is defined as a nonplastic clay or claylike material, usually high in magnesia, which has adequate decolorizing and purifying properties.

Production from the region that includes Attapulgus (Decatur County), Ga., and Quincy (Gadsden County), Fla., is composed predominantly of the lath-shaped amphibole clay mineral attapulgite. Most of the fuller's earth produced in other areas of the United States contains varieties of montmorillonite.

In early 1979, completion of a major expansion was announced by Engelhard Minerals and Chemicals Corp. at its Attapulgus, Ga., mineral thickener operation. Additional modifications scheduled for late 1979 were to further expand production capabilities.

Attapulgite, a fuller's earth-type clay, finds wide application in both the absorbent and thickening areas. Mineral thickeners are used in such diverse markets as paints, joint compound cements, polishes, and plastics. The thixotropic properties of attapulgite clays provide the important thickening and viscosity controls necessary for suspending solids.

Prices for fuller's earth were not publicly quoted in 1979, but the value per ton for attapulgite reported by producers ranged from $28.88 to $63.20; montmorillonite prices ranged from $29 to $55.

In 1979, fuller's earth was exported to 28 countries; exports increased from 59,000 tons in 1978 to 74,000 tons in 1979. The unit value of exported fuller's earth declined $1.68 to $69.90 per ton. The major recipients were the Netherlands, 41%; Canada, 34%; the United Kingdom, 11%; and other countries, the remaining 14%.

Imports of fuller's earth in 1979 were 185 tons valued at $13,000, all from Sweden and the United Kingdom.

Table 18.—Fuller's earth sold or used by producers in the United States, by type and State

Year and State	Attapulgite		Montmorillonite		Total	
	Short tons	Value	Short tons	Value	Short tons	Value
1978						
Florida	453,527	$27,275,039	--	--	453,527	$27,275,039
Georgia	437,183	21,967,804	181,622	$5,178,497	618,805	27,146,301
Other States	[1]29,133	[1]1,406,655	[2]428,154	[2]17,602,520	457,287	19,009,175
Total	919,843	50,649,498	609,776	22,781,017	1,529,619	73,430,515
1979						
Florida	490,843	31,022,860	--	--	490,843	31,022,860
Georgia	432,500	23,088,346	188,661	5,687,180	621,161	28,775,526
Other States	[1]35,954	[1]1,710,602	[2]420,289	[2]20,252,976	456,243	21,963,578
Total	959,297	55,821,808	608,950	25,940,156	1,568,247	81,761,964

[1] Includes Nevada and Texas.
[2] Includes Illinois, Mississippi, Missouri, Nevada, South Carolina, Tennessee, and Utah.

Table 19.—Fuller's earth sold or used by producers in the United States, by type and use

(Short tons)

Use	1978			1979		
	Attapulgite	Montmorillonite	Total	Attapulgite	Montmorillonite	Total
Domestic:						
Adhesives	1,940	--	1,940	1,014	--	1,014
Animal feed	930	--	930	696	--	696
Drilling mud	85,971	26,189	112,160	81,232	23,578	104,810
Fertilizers	53,564	15,774	69,338	62,434	19,796	82,230
Filtering, clarifying, and decolorizing mineral oils and greases	11,227	--	11,227	23,210	--	23,210
Medical, pharmaceutical, cosmetic	81	--	81	122	--	122
Oil and grease absorbents	281,084	191,596	472,680	279,831	165,174	445,005
Paint	8,996	--	8,996	3,902	--	3,902
Paper filling	944	3,245	4,189	746	1,773	2,519
Pesticides and related products	124714	56,294	181,008	131,449	67,847	199,296
Pet waste absorbent	194422	260,249	454,671	202,290	250,177	452,467
Rubber	68	--	68	162	--	162
Miscellaneous	54520	37,365	91,885	49,411	49,398	98,809
Total	818461	590,712	1,409,173	836,499	577,743	1,414,242
Exports:						
Drilling mud	1,125	--	1,125	109	--	109
Oil and grease absorbents	32,289	11,940	44,229	64,712	20,457	85,169
Pet waste absorbent	29,178	5,665	34,843	37,049	9,100	46,149
Miscellaneous	38,790	1,459	40,249	20,928	1,650	22,578
Total	101,382	19,064	120,446	122,798	31,207	154,005
Grand total	919,843	609,776	1,529,619	959,297	608,950	1,568,247

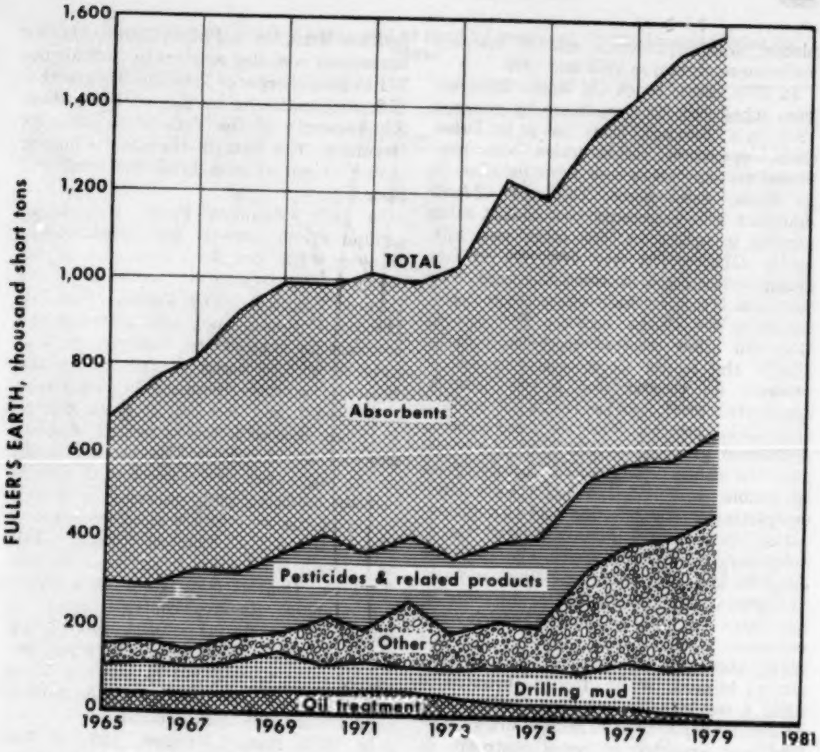

Figure 3.—Fuller's earth sold or used by domestic producers for specified uses.

COMMON CLAY

Domestic production of common clay and shale in 1979 totaled 37.8 million tons valued at $122.7 million. Common clay and shale represented 67% of the quantity and 15% of the value of the total clays in 1979. Domestic clays and shales are for the most part used by the producer in fabricating or manufacturing products. Less than 10% of the total clay and shale output was sold. The average unit value for all common clay and shale produced in the United States and Puerto Rico in 1979 was $3.29 per short ton, $0.19 more than in 1978. The range in unit value reported for the bulk of the output was from $0.80 to $14.62 per ton.

Common clay is defined as a clay or claylike material which is sufficiently plastic to permit ready mold and vitrification below 1,100°C. Shale is consolidated sedimentary rock composed chiefly of clay minerals that has been both laminated and indurated while buried under other sediments. These materials are used in the manufacture of structural clay products, such as brick and drain tile, portland cement clinker, and bloated lightweight aggregate.

Increased production capacities, new

plants, and acquisitions and/or mergers were commonplace in 1978 and 1979.

In 1978, Acme Brick Co. began construction, scheduled for completion by yearend 1978, on a "Bondset" brick line at its Tulsa, Okla., operation. Construction was completed on one of two new periodic kilns at its Perla, Ark., plant. The new 42-foot-diameter kiln augments two 32-foot kilns already in operation. The other new kiln under construction was designed to fire either natural gas or wood particles. The firm also began reconditioning plant facilities at its Weir, Kans., location. The renovation will allow conversion to solid fuels. Lastly, the Keller Corp. was awarded a contract for constructing a new, highly automated brick works at its Oklahoma City, Okla., location. The new facility, with additional grinding capacity to accommodate the enlargement, was being designed to enable conversion to solid fuel. After completing a new grinding and clay preparation plant in 1977, Michigan Brick Co., a subsidiary of Canada Brick Co. (part of Jannock Ltd., a Canadian holding company in Corunna, Mich.), completed an entirely new brick manufacturing plant, which went onstream early in the year. In another move, Michigan Brick purchased a 90-acre site at Mineral Wells, Tex., to eventually build a two-kiln brickmaking facility with an annual capacity of 70 million bricks. The first was expected to come onstream in early 1980 followed by the other in 1981. Also in 1978, Merry Brothers Brick and Tile Co. at its Augusta, Ga., site began work on a $6.5-million plant expansion. Jenkins Brick Co. planned a major $2-million expansion at its Atlanta brick manufacturing facility which will double its present production capacity. The expansion will include a new tunnel kiln and dryers, along with the ancillary equipment to support the new capacity. Jenkins also has two plants in Alabama.

In 1978, Medusa Corp. sold its Marion Brick Corp. subsidiary to IBSTOCK Corp., a newly formed U.S. arm of Ibstock-Johnsen Ltd., a British brickmaker, for $9 million. Richtex Brick Co., a wholly owned subsidiary of Pomona Corp., purchased the plant and assets of Eastern Brick & Tile Co. of Sumter, S.C. The Eastern plant, closed since January, was scheduled to reopen during midyear in order to develop a new line of residential bricks that will complement Richtex's products. General Shale Products Corp. signed a stock purchase agreement for acquiring the common stock of Chattahoochee Brick Co. in Fulton County, Ga. An agreement was also reached in 1978 for the $11 million merger of Triangle Brick with a U.S. corporation to be formed by Roeben-Klinkerwerke of the Federal Republic of Germany. The firm is Germany's largest manufacturer of face brick and roof and floor tile.

In 1979, Michigan Brick, Inc., broke ground at its recently purchased site in Mineral Wells, Tex., for a new brickmaking facility. The facility will operate in the name of Brazos Brick Co. Pullman Swindell Div. of Pullman, Inc., was awarded the contract for engineering, construction, and procurement of major equipment for the fully automated 70-million-brick-per-year commercial and residential brick works. Pullman Swindell was awarded another contract by Mid-State Tile Co. for a 60-meter-long automated roller hearth tunnel kiln for manufacturing quarry tiles. Installation of the new kiln was at Mid-State's Mount Gilead, N.C., plant and was scheduled to begin production by midyear. Belden Brick Co., Canton, Ohio, awarded a multimillion-dollar turnkey contract, again to Pullman Swindell, for building a new brick plant in Sugar-Creek, Ohio. The plant, expected to be operational by yearend 1980, was to capable of producing up to 40 million sand-molded face brick annually.

In 1979, Ibstock-Johnsen, Ltd., of the United Kingdom continued adding U.S. brick interests. This time it completed a merger agreement with the Glen-Gery Corp., Reading, Pa. The earlier purchase of Marion Brick (seven plants) combined with Glen-Gery's seven give Ibstock-Johnsen a total of 13 plants with a capability of more than 500 million bricks annually.

The output of the energy-intensive common clay and shale industry was hindered again by shortages of fuel and labor. Construction rates rose slightly in 1978 but declined in 1979. Industrywide attention was focusing on coal, sawdust, and woodchip firing, in the Northwest and Southeast, as a possible escape from the high cost and shortages of oil and gas.

Exports of common clay and shale are not collected by the U.S. Department of Commerce. Most countries have local deposits of either clays or shales that are adequate for manufacturing structural clay products, cement clinker, and lightweight aggregates, and thus have no need to import such materials.

Table 20.—Common clay and shale sold or used by producers in the United States, by State[1]

State	1978		1979	
	Short tons	Value	Short tons	Value
Alabama	2,094,447	$8,309,496	1,858,715	$8,622,506
Arkansas	1,077,884	1,557,410	912,215	1,345,165
California	2,327,267	10,069,154	2,389,278	11,388,355
Colorado	500,486	2,461,272	479,365	2,457,515
Connecticut	106,243	324,210	111,578	434,701
Delaware	10,449	7,837	10,800	8,640
Florida	118,393	211,350	159,076	285,014
Georgia	2,325,527	6,241,008	1,642,189	4,710,161
Illinois	698,780	2,749,977	515,319	2,106,156
Indiana	1,275,774	2,479,689	1,184,278	2,325,230
Iowa	894,067	2,694,011	869,676	2,883,074
Kansas	1,160,719	2,314,449	1,060,871	2,635,856
Kentucky	632,933	2,359,165	734,090	2,782,261
Louisiana	516,859	4,785,755	415,516	6,073,392
Maine	99,831	163,895	90,090	163,004
Maryland	948,421	2,642,315	974,881	2,854,067
Massachusetts	155,041	332,939	155,547	367,070
Michigan	2,121,707	6,993,043	2,072,107	7,429,990
Minnesota	174,420	2,089,514	135,474	1,904,984
Mississippi	1,256,174	3,094,095	1,221,404	3,161,494
Missouri	1,434,216	3,816,622	1,497,161	4,350,426
Montana	35,123	124,601	38,178	142,530
Nebraska	146,314	417,837	156,144	453,984
New Jersey	52,213	261,065	51,947	272,722
New Mexico	64,672	108,072	74,307	124,242
New York	658,769	2,121,131	835,581	3,027,177
North Carolina	3,542,473	9,067,127	3,308,345	8,385,151
Ohio	2,972,833	8,072,495	2,700,331	7,204,029
Oklahoma	1,019,460	1,874,322	948,662	1,999,129
Oregon	140,265	261,194	139,188	262,740
Pennsylvania	1,937,265	6,791,485	1,763,164	6,178,081
Puerto Rico	285,522	544,065	259,722	555,757
South Carolina	1,573,869	4,387,858	1,504,744	4,149,283
South Dakota	215,850	267,738	205,460	291,506
Tennessee	987,797	2,816,753	697,069	1,304,844
Texas	3,954,650	13,499,895	3,610,246	11,548,394
Utah	252,652	755,302	340,653	1,076,631
Virginia	1,043,369	3,266,027	1,058,552	3,512,044
Washington	356,771	1,417,738	338,762	1,549,254
West Virginia	343,114	574,887	330,309	591,668
Wyoming	179,579	612,096	186,271	690,193
Other States[2]	283,520	1,189,549	241,629	1,126,707
Total	40,074,738	124,068,443	37,278,808	122,735,117

[1] Includes Puerto Rico.

[2] Includes Arizona, Idaho, Nevada, New Hampshire, North Dakota, Wisconsin.

CONSUMPTION AND USES

The manufacture of heavy clay products (building brick, sewer pipe, and drain, roofing, structural, terra cotta, and other tile), portland cement and clinker, and lightweight aggregate accounted for 38%, 19%, and 10%, respectively, of the total domestic consumption for 1979. In summary, 67% of all clay produced in 1979 was consumed in the manufacture of these clay- and shale-based construction materials. The foregoing clay tonnage relationships were similar to those reported for 1978. The utilization of clays in 1979 for heavy clay products and portland cement decreased 11% and 7%, respectively, over that reported in 1978.

Heavy Clay Products.—The values reported for shipments of heavy clay products for 1979 increased 2% to $1,179 million from the 1978 value of $1,159 million. Trends in the various product categories were less consistent. Thousand-unit counts for building or common face brick decreased 10% in 1979 from that shipped in 1978, shipments of glazed and unglazed ceramic tile and glazed brick decreased 3%, and clay floor and wall tile increased 5%. The tonnage of unglazed structural tile decreased 9%, and vitrified clay sewer pipe and fittings shipped during the year decreased 8%. The value of these shipments decreased 2% for building brick and clay and increased 17% for floor and wall tile. The value

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decreased 5% for clay sewer pipe and remained the same for the structural tiles.

Lightweight Aggregate.—Consumption of clay and shale in the making of lightweight aggregate decreased in 1979 to 5.68 million tons. This was a 3% decrease from the 5.85 million tons used in 1978. This small decrease was attributed to a downturn in construction rates, but uses in the newer markets, such as running tracks, golf courses, potting, and a host of other horticultural applications, continued growing.

The tonnage of raw material mentioned in tables 22 and 25 for lightweight aggregate production refers only to clay and shale and does not include the quantity of slate and blast furnace slag similarly used. In 1979, 590,262 tons of slate was expanded for lightweight aggregate, a 10% increase from the 1978 figure of 537,284 tons. The amount of slag used for lightweight concrete aggregate and in block manufacture decreased 9% from 1,682,144 tons in 1978 to 1,538,000 tons in 1979.

Refractories.—All types of clay were used in manufacturing refractories. Fire clay, kaolin, and bentonites accounted for 59%, 22%, and less than 1%, respectively, of the total clays used for this purpose. Bentonite was used primarily as a bonding agent in proprietary foundry formulations. Minor tonnages of ball clay, fuller's earth, and common clay and shale (the remaining 19%) were also used, primarily as bonding agents.

The tonnage used for refractories in 1979 constituted 8% of the total clays produced. This slight decrease in the use of clay-based refractories in 1979 reversed an upward trend which had continued for 7 years. The previous increases were due primarily to both the continued expansion in refractory aggregate production and an upsurge in the manufacturing of more conventional brick-type refractories. The decline in 1979 was attributable to the steelmaking decline. Refractory aggregates are used mostly in plastic, gunning, ramming, and castable mixes.

Filler.—All clays are used to some extent as fillers in one or more areas of use. Kaolin, fuller's earth, and bentonite are the principal filler clays. Kaolin was used in the manufacture of a large number of products, such as paper, rubber, paint, and adhesives. Fuller's earth was used primarily in pesticides and fertilizers. Clays in pesticides and fertilizers are used either as carriers, diluents, or prilling agents. Bentonites were used mainly in animal feed.

In 1979, 10% of the clay produced was used in filler applications. Of all the clay used for these purposes, kaolin accounted for 87%, fuller's earth 8%, and bentonite 4%. Ball clay, common clay and shale, and fire clay accounted for the remaining 1 %. The total amount of kaolin consumed by this end use category increased 20%. In the individual kaolin categories, an increase of 4% was noted for gypsum products, for paper coating, 2% and a 1% increase in rubber use. Decreases were observed for adhesives (19%), fertilizers (12%), and plastics (7%). Total quantity of fuller's earth used in insecticides and fungicides increased 10%.

Absorbent Uses.—Absorbent uses for clays consumed 1,060,869 tons, or 2% of the total 1979 clay production. Demand for absorbents in 1979 increased 1% over that reported for 1978. Fuller's earth was the principal clay used in absorbent applications; 57% of the entire output was consumed for this purpose. Bentonite was used to a lesser degree. Demand for clays in pet waste absorbent, representing 51% of the 1979 absorbent demand, increased 1% from that reported for 1978. Demand for use in floor absorbents, chiefly to absorb hazardous oily substances, represented the remaining 49% of absorbent demand and increased 3% from the 1978 figure.

Drilling Mud.—Demand for clays in rotary-drilling muds increased 10% in 1979, from 1,256,332 tons in 1978 to 1,381,113 tons. This increase in demand, mostly in exploratory gas well drilling and to a lesser degree in oil well drilling, was spurred by the deregulation of "new" gas introduced into the interstate market after April 6, 1972. Drilling muds consumed 2% of the entire 1979 clay production. Swelling-type bentonite is the principal clay used in drilling mud mixes, although fuller's earth or nonswelling bentonite is also used to a limited extent. Bentonite and fuller's earth accounted for nearly 100% of the total amount of clay used for this purpose. Small amounts of ball clay and kaolin were used in specialized formulations.

Floor and Wall Tile.—Common clay and shale, ball clay, kaolin, and fire clay, in order of demand, were used in manufacturing floor, wall, and quarry tile. This tile end use category accounted for less than 1% of the total clay production in 1979. Demand in 1979, 253,434 tons, decreased 7% from that shown in 1978.

Pelletizing Iron Ore.—Bentonite is used as a binder in forming hard iron ore pellets.

Demand decreased in 1979 to 901,708 tons. This decrease in the use of bentonite for iron ore pelletizing, reflecting a downturn in taconite pellet production because of lower steel demand, was compounded by inroads made by cheaper foreign bentonites into a traditional U.S. clay market. Of the total bentonite produced in 1979, about 22% of the swelling variety was consumed for this purpose. U.S. deposits continued to be the major source for swelling bentonites.

Ceramics.—The total demand for clays in the manufacture of pottery, sanitary ware, china and dinnerware, and related products (excluding clay flower pots) accounted for 2% of the total 1979 clay output. The total clay demand, principally ball and kaolin clays, increased from approximately 871,193 tons in 1978 to approximately 1,211,539 tons in 1979.

Table 21.—Clays sold or used by producers in the United States in 1978, including Puerto Rico, by kind and use

(Short tons)

Use	Ball clay	Bentonite	Common clay and shale	Fire clay (refractory only)	Fuller's earth	Kaolin	Undistributed[1]	Total
Adhesives	513	2,747	--	--	1,940	81,106	--	86,306
Alum (aluminum sulfate) and other chemicals	--	--	--	--	W	294,062	W	296,438
Animal feed	W	211,270	W	--	930	9,717	897	222,814
Building brick:								
Common	W	4,717	3,068,243	W	--	76,942	176,237	3,326,139
Face	W	W	17,051,085	48,203	--	275,027	85,425	17,409,740
Catalysts (oil refining)	W	16,843	--	--	4,527	50,401	W	142,176
Cement, portland	--	W	11,239,751	--	--	29,067	W	11,280,690
China and dinnerware	42,202	--	--	--	--	32,756	--	74,958
Crockery and other earthenware	16,748	W	2,889	W	--	22,790	6,417	48,844
Drilling mud	W	1,144,047	--	--	112,160	--	W	1,256,332
Electrical porcelain	36,329	--	--	--	--	27,842	--	64,171
Fertilizers	--	2,437	--	--	69,338	30,577	--	102,352
Fiberglass, mineral wool, other insulation	W	--	--	--	--	201,040	W	231,960
Filtering, clarifying, decolorizing:								
Animal oil	--	69,411	--	--	--	--	--	69,411
Mineral oils and greases	--	33,717	--	--	11,227	--	--	34,944
Vegetable oils	--	63,184	--	--	--	--	--	63,184
Firebrick, block, shapes	8,619	W	W	1,909,368	--	280,285	12,527	2,210,799
Flower pots	W	W	38,259	1,550	--	18,185	53,825	111,819
Flue linings and high-aluminum (minimum 50% Al_2O_3) refractories	20,959	--	167,005	228,450	--	418,738	--	835,152
Foundry sand	--	1,035,828	--	138,864	--	2,863	--	1,177,555
Glazes, glass, enamels	1,760	W	--	W	--	4,784	3,174	9,718
Grogs and crudes, refractory	4,169	--	--	73,287	--	124,383	--	201,839
Gypsum products	--	W	--	--	W	6,339	8,117	14,456
Ink	--	W	--	--	--	W	--	2,634
Kiln furniture	6,246	--	--	--	--	2,838	--	9,084
Lightweight aggregate:								
Concrete block	--	--	4,068,531	--	--	--	--	4,068,531
Structural concrete	--	W	1,173,418	--	--	--	W	1,173,437
Highway surfacing	--	--	513,411	--	--	--	--	513,411
Other	--	--	91,732	--	--	--	--	91,732

Linoleum and asphalt tile	--	--	7,959	--	--	39,984	--	47,943
Medical, pharmaceutical, cosmetic	W	1,282	--	W	W	1,091	9,581	11,964
Mortar and cement, refractory	57,738	W	203,283	413,562	W	20,100	63,876	758,559
Oil and grease absorbents	--	W	W	--	472,680	--	29,880	502,560
Paint	W	26,980	W	--	8,996	167,300	1,050	204,326
Paper coating	665	1,897	--	--	--	2,238,397	--	2,240,959
Paper filling	W	W	--	--	4,189	764,597	10,518	779,304
Pelletizing (iron ore)	--	939,457	--	--	--	W	W	942,389
Pelletizing (other)	--	--	--	W	--	--	W	19,000
Pesticides and related products	834	4,755	W	--	181,098	33,052	W	234,481
Pet waste absorbent	--	W	W	--	454,671	W	93,159	547,830
Plastics	--	1,420	W	--	1,107	70,209	W	73,071
Plug, tap, and wad	--	W	--	33,311	--	--	W	33,493
Pottery	263,509	--	59,402	10,409	--	13,235	--	346,555
Roofing granules	--	--	W	--	5,881	41,282	W	70,683
Rubber	718	W	--	--	W	338,664	1,197	340,579
Sanitary ware	141,352	--	--	--	--	121,171	--	262,523
Sewer pipe, vitrified	--	W	1,250,067	14,119	W	--	110	1,264,296
Tamping dummies	--	--	6,280	--	--	--	--	6,280
Tile:								
Drain	--	--	400,758	--	--	--	--	400,758
Floor and wall	113,744	--	120,614	W	--	36,523	W	271,581
Quarry	--	--	177,215	W	--	--	W	189,465
Roofing	--	--	103,493	--	--	1,940	--	105,433
Structural	--	--	25,456	--	--	W	W	25,874
Terra cotta	--	--	342	--	--	--	--	342
Other	3,993	73,642	14,294	W	5,484	31,701	W	129,712
Waterproofing and sealing	539	74,399	W	--	--	W	36,353	111,291
Miscellaneous[2]	113,571	102,804	167,458	226,443	75,035	5,573	--	(3)
Undistributed	2,485	59,924	--	--	--	98,888	--	[4]125,711
Exports	99,558	606,844	123,798	28,387	120,446	959,865	--	1,938,898
Total	936,251	4,467,605	40,074,738	3,125,953	1,529,619	6,973,314	(3)	57,107,480

W Withheld to avoid disclosing company proprietary data; included with "Undistributed."

[1] Total of clays indicated by symbol W.

[2] Includes asphalt emulsion, graphite anodes, unknown use, and data indicated by symbol W.

[3] Included with total for each specific use.

[4] Incomplete total; difference included with "Miscellaneous."

Table 22.—Clays sold or used by producers in the United States in 1979, including Puerto Rico, by kind and use

(Short tons)

Use	Ball clay	Bentonite	Common clay and shale	Fire clay (refractory only)	Fuller's earth	Kaolin	Undistributed[1]	Total
Adhesives	549	1,219	--	W	1,014	W	67,312	70,094
Alum (aluminum sulfate) and other chemicals	--	--	--	--	W	349,055	--	349,055
Animal feed	W	184,047	--	--	696	13,053	W	197,796
Building brick:								
Common	W	W	4,050,361	W	--	81,317	14,680	4,146,358
Face	W	W	14,133,603	50,874	--	276,006	26,366	14,486,849
Catalysts (oil refining)	W	4,511	W	--	3,863	62,171	59,948	130,493
Cement, portland	--	W	10,507,323	W	--	12,797	2,155	10,522,275
China and dinnerware	44,476	--	--	--	--	36,793	--	81,269
Crockery and other earthenware	22,506	W	8,272	--	--	12,849	W	43,627
Drilling mud	W	1,276,135	--	--	104,810	W	168	1,381,113
Electrical porcelain	35,060	--	--	--	--	29,681	--	64,741
Fertilizers	--	4,764	--	--	82,230	27,263	--	114,257
Fiberglass, mineral wool, other insulation	W	W	--	--	--	216,513	43,809	260,322
Filtering, clarifying, decolorizing:								
Animal oil	--	87,878	--	--	--	--	--	87,878
Mineral oils and greases	--	9,950	--	--	23,210	--	--	33,160
Vegetable oils	--	18,508	--	--	--	--	--	18,508
Firebrick, block, shapes	8,471	W	W	1,958,089	--	389,273	10,053	2,365,886
Flower pots	--	--	39,401	1,000	--	W	W	40,401
Flue linings and high-aluminum (minimum 50% Al_2O_3) refractories	7,139	--	163,287	190,001	--	54,238	--	414,645
Foundry sand	--	896,273	--	161,142	--	770	--	1,057,415
Glasses, glass, enamels	1,644	W	--	--	--	3,601	W	5,245
Grogs and crudes, refractory	4,292	W	--	90,303	--	570,324	W	666,551
Gypsum products	--	W	--	--	W	6,582	11,199	81,982
Ink	--	W	--	--	--	W	--	2,046
Kiln furniture	2,187	--	23,200	--	--	2,293	--	27,680
Lightweight aggregate:								
Concrete block	--	--	3,804,138	--	--	--	--	3,804,138
Structural concrete	--	--	1,261,981	--	--	--	--	1,261,981
Highway surfacing	--	--	470,894	--	--	--	--	470,894

Other	--	--	144,258	--	--	--	--	144,253
Linoleum and asphalt tile	6,042	--	1,434	--	--	43,541	--	51,017
Medical, pharmaceutical, cosmetic	W	3,295	--	W	W	2,309	9,627	15,231
Mortar and cement, refractory	77,339	--	198,480	368,569	W	36,715	W	681,108
Oil and grease absorbents	--	W	W	--	445,005	W	37,226	519,457
Paint	W	13,905	W	--	3,902	169,123	840	188,610
Paper coating	782	W	--	--	W	2,276,575	466	2,278,289
Paper filling	W	W	--	--	W	861,107	14,979	891,065
Pelletizing (iron ore)	--	901,708	--	--	--	W	W	901,708
Pelletizing (other)	--	W	--	W	--	--	--	14,317
Pesticides and related products	732	4,190	W	--	199,296	46,056	W	250,274
Pet waste absorbent	--	W	W	--	452,467	W	88,945	541,412
Plastics	--	W	W	--	W	65,233	2,550	67,783
Plug, tap, and wad	--	--	--	6,250	--	--	--	6,250
Pottery	247,061	--	232,388	16,092	--	32,724	--	528,265
Roofing granules	--	--	W	--	W	14,219	28,486	42,705
Rubber	W	W	--	--	W	342,012	2,363	344,375
Sanitary ware	151,605	--	--	--	--	146,989	--	298,594
Sewer pipe, vitrified	--	W	1,009,627	W	W	W	45,119	1,014,176
Tamping dummies	--	--	6,280	--	--	W	W	6,280
Tile:								
Drain	--	--	311,891	--	--	--	--	311,891
Floor and wall	113,440	W	111,014	W	--	27,320	830	253,484
Quarry	--	--	188,933	--	--	W	W	188,933
Roofing	--	W	102,490	--	--	W	742	103,232
Structural	--	--	36,554	--	--	W	W	36,554
Terra cotta	--	--	1,511	--	--	--	--	1,511
Waterproofing and sealing	--	75,693	--	--	--	706	--	76,399
Miscellaneous[2]	25,770	109,672	241,414	31,210	6,051	87,291	--	508,595
Undistributed	115,257	124,232	150,377	39,522	91,698	80,958	148,342	[1]36,792
Exports	122,660	706,095	79,717	19,291	154,005	1,383,148	--	2,464,916
Total	987,012	4,422,075	37,278,808	2,932,348	1,568,247	7,760,600	(4)	54,949,080

W Withheld to avoid disclosing company proprietary data; included with "Undistributed."

[1] Total of clays indicated by symbol W.

[2] Includes asphalt emulsion, graphite anodes, unknown use, and data indicated by symbol W.

[3] Incomplete total; difference included with "Miscellaneous."

[4] Included with total for each specific use.

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Table 23.—Shipments of principal structural clay products in the United States

Products	1975	1976	1977	1978	1979
Unglazed common and face brick:					
Quantity .... million standard brick	5,854	6,973	8,060	8,957	8,020
Value .... million dollars	$358	$461	$607	$765	$749
Unglazed structural tile:					
Quantity .... thousand short tons	88	71	50	76	69
Value .... million dollars	$4	$3	$3	$4	$4
Vitrified clay and sewer pipe fittings:					
Quantity .... thousand short tons	1,190	1,099	1,140	924	847
Value .... million dollars	$124	$123	$140	$126	$120
Unglazed, salt glazed, and ceramic glazed structural facing tile, including glazed brick:					
Quantity .... million equivalent	79	62	63	58	56
Value .... million dollars	$11	$10	$11	$11	$11
Clay floor and wall tile, including quarry tile:					
Quantity .... million square feet	236	259	291	299	314
Value .... million dollars	$159	$186	$233	$253	$295
Total value .... do	$656	[1]$784	$994	$1,159	$1,179

[1] Data do not add to total shown because of independent rounding.

Table 24.—Common clay and shale used in building brick production in the United States, by State

State	1978		1979	
	Short tons	Value	Short tons	Value
Alabama	826,002	$2,054,544	701,542	$1,826,936
Arizona and New Mexico	131,739	250,588	119,248	260,306
Arkansas	585,631	939,703	468,020	760,395
California	572,403	2,651,607	500,159	1,547,856
Colorado	468,067	2,334,866	447,600	2,325,290
Connecticut	105,243	324,466	111,578	435,179
Delaware	10,449	7,837	10,800	8,640
Georgia	2,032,815	5,555,808	1,362,559	4,021,976
Idaho, Montana, Utah	143,897	489,235	107,135	522,764
Illinois	405,964	1,760,655	317,504	1,478,969
Indiana and Iowa	740,082	1,545,665	682,173	1,612,956
Kansas	325,883	765,428	220,629	425,635
Kentucky	197,137	499,670	266,955	808,311
Louisiana	219,888	438,757	139,516	273,392
Maine, Massachusetts, New Hampshire	180,959	478,623	149,256	339,722
Maryland and West Virginia	487,132	1,465,006	461,687	1,721,822
Michigan, Minnesota, Wisconsin	220,380	1,941,407	239,510	2,310,267
Mississippi	919,873	2,115,567	829,356	2,298,697
Missouri	225,232	663,708	218,411	672,756
Nebraska and North Dakota	173,173	406,607	165,356	419,284
New Jersey	50,000	250,000	50,000	262,500
New York	228,718	552,890	247,409	575,284
North Carolina	2,834,030	7,658,508	2,667,030	6,981,229
Ohio	1,488,805	4,211,900	1,400,467	3,519,424
Oklahoma	399,713	747,789	400,030	793,578
Oregon	50,152	79,756	42,438	73,185
Pennsylvania	1,478,888	4,791,804	1,427,168	4,811,100
South Carolina	1,109,866	3,015,445	978,527	2,731,157
South Dakota	10,494	13,118	--	--
Tennessee	560,725	914,428	479,281	828,994
Texas	1,760,044	7,375,944	1,771,786	5,775,762
Virginia	937,289	1,702,713	956,472	1,870,953
Washington	197,146	689,584	201,134	801,600
Wyoming	41,509	202,039	43,228	244,061
Total	20,119,328	58,895,610	18,183,964	53,339,980

Table 25.—Clay and shale used in lightweight aggregate production in the United States, by State and kind

State	Short tons					Total value
	Concrete block	Structural concrete	Highway surfacing	Other	Total	
1978						
Alabama and Arkansas	1,059,532	159,459	12,808	13,665	1,245,464	$5,288,765
California	282,600	176,979	--	60	459,639	3,427,700
Colorado, Florida, Georgia	36,000	24,000	--	--	60,000	129,600
Illinois, Indiana, Iowa	343,261	11,900	350	--	355,511	1,266,528
Kansas, Kentucky, Louisiana	452,564	125,659	65,944	7,491	651,658	5,204,097
Maryland, Massachusetts, Minnesota	115,375	25,189	--	27,566	168,130	2,013,262
Mississippi	144,817	32,832	203,010	--	380,659	797,799
Missouri, Nebraska, North Carolina	356,386	152,800	12,150	--	521,336	1,591,452
Montana	8,800	--	--	--	8,800	14,080
New York	148,000	90,000	--	1,250	239,250	1,261,345
North Dakota, Ohio, Pennsylvania	241,084	23,276	5,130	200	269,640	970,789
Oklahoma	110,790	64,346	--	--	175,136	306,489
South Dakota, Utah, Washington	138,505	58,454	326	--	197,285	457,602
Tennessee	196,215	--	--	--	196,215	1,486,543
Texas	336,752	227,424	213,693	36,500	814,369	2,580,754
Virginia	97,900	1,100	--	5,000	104,000	1,560,000
Total	4,068,581	1,178,418	513,411	91,732	5,847,092	28,301,805
1979						
Alabama and Arkansas	999,176	136,471	25,094	--	1,160,741	5,775,898
California	298,082	299,382	--	67,331	664,795	5,848,595
Illinois, Indiana, Iowa	324,172	--	--	--	324,172	1,029,926
Kansas, Kentucky, Louisiana	466,082	161,738	85,496	7,870	721,186	7,740,970
Massachusetts and Minnesota	121,914	17,483	--	3,979	143,376	1,945,792
Mississippi	121,058	30,830	200,165	--	352,048	772,947
Missouri, Nebraska, North Carolina	364,831	134,000	12,150	--	510,981	1,862,236
Montana	9,475	--	--	--	9,475	15,160
New York	214,750	138,250	--	1,300	354,300	2,053,661
North Dakota, Ohio, Pennsylvania	251,105	638	5,225	--	256,968	989,327
Oklahoma	116,125	67,246	--	--	183,371	361,256
South Dakota, Utah, Washington	195,557	110,199	326	--	306,082	821,426
Texas	234,286	155,324	142,438	61,773	593,821	1,994,794
Virginia	97,000	1,000	--	2,000	100,000	1,638,000
Total	3,813,558	1,252,561	470,894	144,253	5,681,266	32,819,988

Table 26.—Shipments of refractories in the United States, by kind

Product	Unit of quantity	1978		1979	
		Quantity	Value (thousands)	Quantity	Value (thousands)
CLAY REFRACTORIES					
Superduty fire clay brick and shapes	1,000 9-inch equivalent	54,481	$42,393	61,538	$79,446
Other fire clay, including semisilica, brick and shapes, glasshouse pots, tank blocks, feeder parts, and upper structure parts used only for glass tanks.	do	176,580	83,583	162,517	89,193
High-alumina (50% to 60% Al_2O_3) brick and shapes made of calcined diaspore or bauxite.[1]	do	77,491	113,553	83,869	135,948
Insulating firebrick and shapes	do	47,387	29,860	49,321	33,049
Ladle brick	do	185,618	48,714	192,965	52,463
Sleeves, nozzles, runner brick, tuyeres	do	36,572	25,984	46,239	35,514
Hot-top refractories	Short tons	27,934	4,152	22,932	6,244
Kiln furniture, radiant heater elements, potter's supplies, other miscellaneous-shaped refractory items.	do	NA	19,429	NA	21,843
Refractory bonding mortars	do	79,462	19,539	88,452	25,876
Plastic refractories and ramming mixes, containing up to 87.5% Al_2O_3.[2]	do	102,939	38,274	205,784	44,624
Castable refractories	do	161,830	32,792	153,821	33,084
Gunning mixes	do	63,398	10,326	87,800	15,396
Other clay refractory materials sold in lump or ground form.[3] [4]	do	320,538	28,968	92,450	7,577
Total clay refractories		XX	497,567	XX	580,257
NONCLAY REFRACTORIES					
Silica brick and shapes	1,000 9-inch equivalent	30,574	33,607	44,996	42,059
Magnesite and magnesite-chrome brick and shapes.	do	100,150	268,627	95,670	285,792
Chrome and chrome-magnesite brick and shapes.	do	13,060	38,063	10,843	36,603
Shaped refractories containing natural graphite.	Short tons	22,429	31,131	25,408	36,435
Zircon and zirconia brick and shapes; other carbon refractories: Forsterite, pyrophyllite, dolomite, dolomite-magnesite, molten-cast,[5] other brick and shapes.	1,000 9-inch equivalent	35,684	152,997	39,624	168,287
Other mullite, kyanite, sillimanite, or andalusite brick and shapes.	do	3,651	15,641	4,651	19,223
Other extra-high (over 60%) alumina brick and fused bauxite, fused alumina, and dense-sintered alumina shapes.[6]	do	7,223	31,631	9,043	44,163
Silicon carbide brick, shapes, and kiln furniture.	do	4,048	34,708	4,842	47,094
Refractory bonding mortar	Short tons	35,103	14,114	33,978	15,626
Hydraulic-setting nonclay refractory castables.	do	43,937	20,726	44,098	25,615
Plastic refractories and ramming mixes	do	206,342	82,409	246,915	94,982
Gunning mixes	do	385,543	85,690	403,493	99,147
Dead-burned magnesia or magnesite[3] [7]	do	567,245	108,232	630,962	127,198
Other nonclay refractory material sold in lump or ground form.[3]	do	670,393	62,294	665,789	64,441
Total nonclay refractories		XX	979,870	XX	1,106,775
Grand total refractories		XX	1,477,437	XX	1,687,032

NA Not available. XX Not applicable.

[1] Heated short of fusion; volatile materials are thus driven off in the presence of chemical changes, giving more stable material for refractory use.

[2] More or less plastic brick and materials which, after the addition of any water needed, are rammed into place.

[3] Materials for domestic use as finished refractories, and all exported material.

[4] Including calcined clay, ground brick, and siliceous and other gunning mixes.

[5] Molten cast refractories are made by fusing refractory oxides and pouring the molten material into molds to form finished shapes.

[6] Completely melted and cooled, then crushed and graded for use in a refractory.

[7] Includes shipments to refractory producers for reprocessing in the manufacture of other refractories.

Table 27.—U.S. exports of clay by country and class in 1978

(Thousand short tons and thousand dollars)

Country	Ball clay		Bentonite		Fire clay		Fuller's earth		Kaolin		Clays, n.e.c.		Total	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Argentina	(1)	1	(1)	184	(1)	8	(1)	10	18	1,825	(1)	281	18	2,309
Australia	(1)	14	38	1,593	15	792	(1)	37	7	639	18	2,279	78	5,354
Belgium-Luxembourg	--	--	(1)	26	4	177	2	118	8	907	1	206	15	1,434
Brazil	1	55	8	684	2	141	(1)	14	4	645	2	780	17	2,319
Brunei	--	--	7	617	--	--	--	--	--	--	(1)	39	7	656
Canada	43	1,101	309	13,280	59	3,059	17	1,070	186	10,366	96	7,012	710	35,888
Chile	(1)	11	5	644	--	--	(1)	12	1	176	1	244	7	1,087
China, Taiwan	2	60	8	743	(1)	40	--	--	29	2,911	8	435	47	4,189
Colombia	(1)	8	2	182	(1)	23	(1)	45	4	437	1	279	7	974
Egypt	--	--	10	1,011	--	--	1	178	--	--	(1)	402	11	1,591
Finland	--	--	4	210	--	--	--	--	1	85	(1)	4	5	299
France	(1)	86	2	480	(1)	38	3	313	28	2,901	13	1,597	46	5,415
Germany, Federal Rebublic of	(1)	54	19	1,117	72	3,676	1	96	153	11,817	29	2,630	274	19,390
Guatemala	(1)	2	(1)	57	(1)	6	1	44	3	241	(1)	18	4	368
Honduras	--	--	2	188	--	--	(1)	17	1	122	(1)	18	3	345
Indonesia	--	--	19	910	(1)	4	--	--	1	102	(1)	52	20	1,068
Israel	(1)	7	2	390	(1)	45	(1)	6	(1)	35	1	137	3	620
Italy	(1)	57	1	168	8	436	1	69	156	12,170	13	1,279	179	14,179
Japan	2	113	62	4,574	24	1,625	(1)	17	374	32,457	56	5,138	518	43,919
Korea, Republic of	1	50	8	376	(1)	6	(1)	8	22	2,869	1	166	26	3,475
Mexico	80	1,867	7	1,385	38	1,151	(1)	5	57	3,882	17	1,261	199	9,551
Netherlands	(1)	8	39	1,631	(1)	51	22	1,015	35	2,284	18	1,741	114	6,739
New Zealand	--	--	(1)	56	(1)	6	(1)	30	3	234	1	241	4	567
Peru	--	--	1	61	--	--	(1)	17	2	195	(1)	132	3	405
Philippines	3	146	1	315	1	53	(1)	2	7	587	1	163	13	1,266
Saudi Arabia	(1)	1	38	1,360	--	--	--	--	(1)	1	6	870	44	2,232
Singapore	--	--	43	1,955	--	--	(1)	26	(1)	43	3	450	46	2,474
South Africa, Republic of	(1)	10	1	330	--	--	(1)	10	15	1,741	1	281	17	2,372
Spain	--	--	1	154	(1)	42	(1)	98	8	708	(1)	114	9	1,116
Sweden	--	--	(1)	8	5	361	(1)	2	2	140	2	289	9	800
Switzerland	--	--	(1)	40	(1)	7	(1)	7	1	55	13	777	14	886

See footnotes at end of table.

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Table 27.—U.S. exports of clay by country and class in 1978 —Continued

(Thousand short tons and thousand dollars)

Country	Ball clay		Bentonite		Fire clay		Fuller's earth		Kaolin		Clays, n.e.c.		Total	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Thailand	--	--	2	276	--	--	--	--	3	271	(1)	138	5	685
United Arab Emirates	--	--	7	955	--	--	1	174	--	--	2	230	10	1,359
United Kingdom	(1)	11	37	2,272	5	93	8	440	5	508	12	2,425	67	5,749
Venezuela	8	468	32	2,127	2	88	(1)	37	22	1,927	4	806	68	5,453
Other	4	136	14	2,893	1	92	2	306	18	2,089	9	2,874	48	8,390
Total	144	4,266	[2]723	43,252	236	12,020	59	4,228	1,174	95,370	329	35,783	2,665	194,914

[1] Less than 1/2 unit.

[2] Data do not add to total shown because of independent rounding.

Table 28.—U.S. exports of clay by country and class in 1979

(Thousand short tons and thousand dollars)

Country	Ball clay		Bentonite		Fire clay		Fuller's earth		Kaolin		Clays, n.e.c.		Total[1]	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Argentina	--	--	(2)	323	--	--	(2)	22	22	2,470	1	317	23	3,131
Australia	(2)	2	76	2,959	22	1,243	(2)	92	26	2,117	8	2,013	133	8,426
Belgium-Luxembourg	(2)	2	1	80	6	357	1	59	11	1,185	2	1,332	21	3,014
Brazil	1	105	15	1,450	1	97	--	--	6	997	2	1,090	25	3,738
Canada	51	1,391	367	17,928	45	2,954	25	1,560	226	14,338	79	8,177	794	46,348
Chile	(2)	11	3	519	(2)	1	(2)	3	2	330	2	812	8	1,677
China, Taiwan	3	145	8	897	3	122	--	--	30	3,313	6	465	49	4,942
Colombia	1	15	8	710	1	121	1	145	4	440	(2)	186	14	1,617
Ecuador	1	46	1	110	(2)	27	(2)	11	1	56	(2)	13	3	264
Finland	--	--	5	192	--	--	--	--	(2)	12	(2)	6	6	210
France	--	--	1	265	(2)	34	2	263	25	2,915	9	1,362	37	4,839
Germany, Federal Rebublic of	(2)	16	2	268	60	3,480	1	76	307	12,721	20	1,975	390	18,535
Guatemala	(2)	11	1	181	(2)	3	(2)	23	3	266	1	72	5	556
Hong Kong	(2)	18	1	169	--	--	--	--	1	89	1	71	3	346
Indonesia	--	--	11	632	--	--	--	--	(2)	63	(2)	71	11	767
Italy	(2)	9	1	192	3	231	(2)	67	185	16,496	2	944	191	17,940
Japan	2	100	68	7,046	28	2,490	(2)	7	458	40,624	62	6,732	618	56,998
Korea, Republic of	1	43	2	595	(2)	7	(2)	6	24	3,740	(2)	31	27	4,423
Mexico	98	2,608	16	2,920	42	1,368	(2)	13	76	5,664	29	2,589	261	15,162
Netherlands	(2)	24	72	3,007	(2)	118	30	1,459	73	6,991	21	1,516	196	13,114
New Zealand	(2)	2	1	93	--	--	1	45	3	246	(2)	272	5	658
Peru	--	--	2	271	--	--	(2)	69	3	445	(2)	194	8	960
Philippines	5	254	4	573	1	45	(2)	1	7	784	1	138	17	1,795
Saudi Arabia	--	--	39	2,563	--	--	(2)	52	(2)	21	3	545	43	3,181
Singapore	--	--	30	1,709	(2)	(2)	(2)	1	(2)	53	(2)	208	30	1,972
South Africa, Republic of	(2)	8	2	443	(2)	2	(2)	21	20	2,035	(2)	248	23	2,757
Spain	--	--	6	347	(2)	33	(2)	2	10	700	(2)	235	17	1,317
Sweden	(2)	8	(2)	22	4	231	(2)	1	12	977	5	744	22	1,982
Switzerland	--	--	(2)	19	(2)	18	(2)	5	1	65	15	961	17	1,068
Thailand	(2)	1	2	398	--	--	--	--	1	244	--	--	3	644
Trinidad	(2)	1	2	593	--	--	--	--	(2)	19	1	89	3	701

See footnotes at end of table.

Table 28.—U.S. exports of clay by country and class in 1979 —Continued

(Thousand short tons and thousand dollars)

Country	Ball clay		Bentonite		Fire clay		Fuller's earth		Kaolin		Clays, n.e.c.		Total[1]	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
United Arab Emirates	--	--	1	192	--	--	2	315	--	--	(2)	122	4	628
United Kingdom	(2)	11	46	2,636	2	134	8	529	10	1,264	16	2,181	83	6,755
Venezuela	3	234	33	1,817	3	175	(2)	39	22	2,087	4	838	65	5,189
Other	3	187	23	3,134	2	261	2	287	14	2.177	7	2,001	51	8,047
Total[1]	169	5,250	853	55,252	224	13,551	74	5,173	1,583	125,946	300	38,550	3,205	243,722

[1] Data may not add to totals shown because of independent rounding.
[2] Less than 1/2 unit.

Table 29.—U.S. imports for consumption of clay

Kind	1978 Quantity (short tons)	1978 Value (thousands)	1979 Quantity (short tons)	1979 Value (thousands)
China clay or kaolin, whether or not beneficiated:				
Canada	364	$21	981	$51
France	44	8	--	1
Germany, Federal Republic of	--	1	11	2
Japan	29	12	81	40
Netherlands	--	--	41	4
United Kingdom	12,358	812	30,342	1,788
Total	12,795	854	31,456	1,886
Fuller's earth, not beneficiated:				
Germany, Federal Republic of	1	(1)	--	--
United Kingdom	54	9	105	13
Total	55	9	105	13
Fuller's earth, wholly or partly beneficiated:				
Germany, Federal Republic of	1	(1)	--	--
Mexico	28	2	--	--
Sweden	--	--	80	(1)
Total	29	2	80	(1)
Bentonite:				
Canada	9	5	26	23
Germany, Federal Republic of	32	8	24	7
Mexico	6	(1)	--	--
Taiwan	--	--	28	2
United Kingdom	--	--	4	5
Total	47	13	82	37
Common blue and other ball clay, not beneficiated:				
Canada	--	--	1,319	55
Netherlands	--	--	1,503	75
South Africa, Republic of	188	3	--	--
United Kingdom	3,217	196	4,330	231
Total	3,405	199	7,152	361
Common blue and other ball clay, wholly or partly beneficiated:				
Germany, Federal Republic of	--	--	1	1
United Kingdom	3,881	222	5,590	380
Total	3,881	222	5,591	381
Other clays, not beneficiated:				
Canada	--	(1)	197	9
France	6	1	--	--
Germany, Federal Republic of	114	22	162	95
Saudi Arabia	2	1	--	--
Spain	57	4	2,237	131
Taiwan	2	1	--	--
United Kingdom	1	1	--	--
Total	182	30	2,596	235
Clays, n.e.c., wholly or partly beneficiated:				
Canada	--	--	92	15
Denmark	--	--	7	1
France	42	6	--	--
Germany, Federal Republic of	264	59	177	41
Japan	18	9	--	--
Mexico	--	--	139	9
Netherlands	--	--	59	13
Spain	25	1	25	1
United Kingdom	1,434	210	1,142	216
Total	1,783	285	1,641	296
Artificially activated clay:				
Canada	1,370	114	1,095	116
Germany, Federal Republic of	306	188	730	527
Japan	135	58	--	--
Mexico	783	108	650	100
United Kingdom	--	--	20	20
Total	2,594	468	2,495	763
Grand total	24,771	2,062	51,198	3,972

[1] Less than 1/2 unit.

WORLD REVIEW

Algeria.—The state concern, SONAREM, was looking for bids, closed October 15, 1979, for a study into developing the known kaolin reserves at Tamazert.

Australia.—Kaiser Refractories Ltd., the Australian subsidiary of the U.S. company, agreed in 1978 to acquire the assets of Newbold General Refractories Ltd. Div. from Manufacturing Resources of Australia Ltd. Newbold's production consists of clay/alumina bricks and monolithics and silica bricks. Newbold's ceramic and heavy clay products were not included in the sale. Also in 1978, the $7 million brick plant of Columbus Brick Pty. Ltd. began operations at Warnervale, near Wyong, 80 miles north of Sydney. Initial plant production began with 1 million bricks per month, but plans were afoot to reach 3.5 million bricks monthly. Two additional building brick events occurred during the year. In the first, Midland Brick Co. completed its new $7 million tunnel kiln and ancillary facilities in Perth, Western Australia. The new kiln was reported to be the world's largest. The other event was a $12 million, highly automated 6-million-brick-per-year plant, 25 miles west of Sydney. This new plant, built by Pacific Brick Pty. Ltd., a joint venture of the Broken Hill Pty. subsidiary, Australian Industrial Refractories Ltd., and a group of local businessmen, is located on the clay and shale quarry site.

The new attapulgite processing and packaging plant of Mallina Holdings Ltd. was opened at Geraldton, Western Australia, at yearend 1979. The new $2 million facility will manufacture a range of coarse-to-fine products from clay supplied from deposits at Nerrarmye, 80 miles northeast of Geraldton. Also in 1979, a preliminary agreement to develop a 250,000-ton-per-year kaolin deposit about 80 miles northeast of Perth was signed by Engelhard Minerals and Chemicals Corp. The $30 million project was originally undertaken by Consolidated Gold Fields Australia Ltd. and West Australian Kaolin Pty Ltd. The current reserves are estimated to contain at least 10 years' supply.

Brazil.—After the United States, the United Kingdom, and the U.S.S.R., Brazil is the world's fourth largest supplier of paper coating-quality kaolin. One company, Caulim Da Amazonia Ltda., of the Ludwig Group, located along the Jarí River on the Pará-Amapá border in the Amazon region, is currently in production. A second kaolin project is being developed in the Capim River area of Pará by Caulim do Pará Ltd., a joint venture of the Brazilian Constructura Mendes Junior Group and the U.S. kaolin producer, J. M. Huber Corp. The $60 million mine and processing facilities, scheduled for completion in 1980, were to have a capacity of nearly 300,000 tons annually. During 1979, additional production came from smaller producers concentrated in the States of Rio Grande do Norte, Pernambuco, Baía, Paraíba, Minas Gerais, and São Paulo. The Brazilian reserves of all kaolin grades were estimated at 342 million tons measured, 268 million tons indicated, and 6 million tons inferred.

Burma.—The recent Japanese-built ceramic plant at Tharawaddy has resulted in not only an increase in domestic kaolin production in 1979, but also a resumption of ball clay production.

Canada.—The $1.4 million bentonite processing plant of Avonlea Mineral Industries Ltd. of Regina, Saskatchewan, was completed in early 1978. The 60,000-ton-per-year plant, partially financed by the Government, will be processing ore from a mine near Avonlea, 30 miles southwest of Regina. The deposits, according to reports, contain 1.6 million tons of iron-ore-pelletizing- and oil well drilling-quality material. Clayburn Industries Ltd., British Columbia, announced in 1979 its plans to invest up to $11 million to expand its brick works in Abbotsford. The new expansion was to be fully automated and increase manufacturing capacity by 25%. Another expansion was announced during the year by I-XL Industries Ltd., Medicine Hat, Alberta, at its Red Cliff Pressed Brick Division works. Completion of the project, planned to double the plant's capacity at a cost of more than $4 million, was targeted for the spring of 1980.

China, mainland.—A deposit of high-grade sodium bentonite, containing over 10 million tons of ore, was located in the Lin-An district west of Hangchow in Zhejiang Province in 1979. Another deposit of unreported size was discovered at Tuokehshun in Xinjiang Province.

Colombia.—A new, $2 million plant was planned to process clay from near the town of Union in the State of Antioquia. The plant, in 1979, was scheduled to supply the State's paper, paint, and rubber needs and was to be built by a newly established company, Minerales Industriales S.A.

Egypt.—Proven reserves of 16.3 million tons of raw kaolin, free of sand particles, were claimed in 1979 by the Geological Survey Organization for the main deposits located at Kalabasha, approximately 60 miles west of Aswan.

Finland.—EEC International (EEC's foreign sales organization) created a new subsidiary, EEC International Oy, headquartered in Helsinki. The move appears to show concern for the strong position of Finnish talcs in paper filling.

Ghana.—Two kaolin deposits, one northeast of Kibi on the Atewa Range, Eastern Region, and the other in the Central Region at the Abandze-Saltpond bypass, were estimated by the Government in 1979 to contain over 5 million tons of ceramic-quality clay. The Kibi ore is associated with bauxite deposits, and the other deposit is derived from weathered pegmatites.

Guyana.—In 1978, the Government was planning to produce kaolin from one of its large kaolin deposits and was also seeking a partner to provide the venture with the necessary technical and marketing expertise. The Government envisions an Ituni area plant capable of producing 100,000 to 150,000 tons annually of paper-grade clay near the known reserves at Topira. Reserves at Topira and close-by areas are reportedly in excess of 5.0 million tons.

India.—In 1979, large deposits of bentonite, containing more than 90 million tons scattered over a 12-square-mile area, have been found in the Jhalawar district of Rajasthan. The State-owned mineral development corporation is understood to be interested because of the export potential for the bentonite, in particular to Middle Eastern countries.

Indonesia.—The largest commercial kaolin deposits were reported to occur in Belitung and Bangka Islands and in northern Sulawesi. Production in 1979 was exported principally to Japan and Taiwan.

Japan.—EEC acquired a 50% interest in Fuji Kaolin Co. Ltd. in 1979, thereby halving ITC Japan Ltd.'s holding. Fuji Kaolin was originally set up by Ataka and Co. to import raw clay from the U.S.S.R. for upgrading to paper coating and filling grades. ITC Japan, a subsidiary of ITC Enterprises, Baltimore, Md., took over the Fuji plant after operating difficulties. ITC Japan has marketed Georgia kaolin in Japan for years.

Pakistan.—In a 1978 study, the Government's Geological Survey reported the discovery of large kaolin deposits near Nagarparkar in the Thar Desert of Sind. Neither the grade nor size of the deposit was announced.

Portugal.—Sibelco Porgugesa Ltda., owned by the Belgian SCR Sibelco and a local glassmaker, Covina-Companhia Vidreira Nacional, was scheduled to begin producing glass sand and kaolin from its sand kaolin deposit at Rio Maior in 1980. Production levels in the 1979 announcement were not stipulated.

Saudi Arabia.—The Government granted a multimillion-dollar contract to Pullman Swindell, Div. of Pullman Inc. to design, construct, and put into service another brick work in Jeddah. This second plant ordered from Pullman was to be built adjacent to the first one, which was completed in 1978. These plants were to manufacture both the indigenous type of hollow clay bricks and the U.S. varieties of residential face bricks.

Thailand.—The major kaolin production centers are in Lampang and Uttaradit in the north and Ranong and Narathiwat in the south. Kaolin of commercial value is known also to occur in other parts of the country. The entire kaolin output is consumed domestically by the ceramic, paint, and paper industries.

United Kingdom.—AMAX Exploration UK Ltd., part of the joint venture formed with Hemerdon Mining and Smelting Ltd. of Bermuda to explore the Hemerdon china clay, tungsten, tin, and silica deposit near Plymouth, in 1978 was planning to exercise its option and proceed to the third stage of the project which involves drilling, trenching, and metallurgical testing. An option agreement was also signed by the AMAX-Hemerdon (A-H) joint venture and English Clays Lovering Pochin Ltd. (ECLP) to permit A-H to explore ECLP's adjacent kaolin workings for metal values. The agreement also gives A-H the right to enter into a mining lease, and ECLP a mineral royalty and rights to clays produced from its property, including the right of first refusal to buy minerals produced by A-H.

Two fuller's earth actions also occurred during 1978. In the first, the Secretary of State for the Environment, after assurances that the localities' interests were protected, has permitted the continued mining of fuller's earth at Apsley Heath, Woburn Sands,

Table 30.—Kaolin: World production, by country

(Thousand short tons)

Country[1]	1976	1977	1978[p]	1979[e]
North America:				
Costa Rica	1	1	1	1
Mexico	79	197	198	198
United States[2]	6,115	6,469	6,973	[3]7,800
South America:				
Argentina	92	82	84	90
Brazil (beneficiated)	231	286	1,273	1,300
Chile	74	61	53	50
Colombia	[r] [e]120	869	863	875
Ecuador	1	2	1	1
Paraguay	15	24	39	30
Peru	10	12	4	5
Venezuela	[r]9	11	25	20
Europe:				
Austria (marketable)	79	82	85	80
Belgium[e]	[r]130	[r]130	130	130
Bulgaria	214	214	219	220
Czechoslovakia	601	639	653	660
Denmark[e]	[r]25	[r]25	25	22
France	302	[r] [e]310	280	275
Germany, Federal Republic of (marketable)	487	551	574	600
Greece	[r]85	72	55	60
Hungary	[r]95	79	75	75
Italy:				
Crude	90	90	78	80
Kaolinitic earth	29	22	4	NA
Poland	[r]104	100	73	80
Portugal	[r]70	80	67	60
Romania[e]	100	100	100	100
Spain (marketable)[4]	228	125	[e]130	125
U.S.S.R.[e]	2,400	2,500	2,600	2,800
United Kingdom	4,241	4,782	4,629	5,000
Africa:				
Algeria	9	18	19	20
Angola[e]	--	1	--	NA
Burundi	3	[e]3	[e]3	3
Egypt	31	54	61	65
Ethiopia (including Eritrea)	50	[e]45	35	35
Kenya	[r] ([5])	1	2	NA
Madagascar	28	2	3	3
Mozambique	1	--	--	--
Nigeria	[e]1	1	2	NA
South Africa, Republic of	66	98	135	[3]164
Swaziland	1	--	--	--
Tanzania[e]	1	1	1	1
Asia:				
Bangladesh	2	[e]5	[e]7	7
Hong Kong	1	3	3	3
India:				
Salable	[r]369	385	356	365
Processed	114	106	111	115
Indonesia	32	40	38	40
Iran	220	123	198	NA
Israel	11	6	7	8
Japan	249	250	250	250
Korea, Republic of	418	393	404	[3]413
Malaysia	29	35	34	35
Pakistan	[r] ([5])	1	15	17
Sri Lanka	5	6	6	6
Taiwan	30	32	73	[3]94
Thailand	18	27	37	[3]47
Turkey	[r]61	65	48	65
Oceania:				
Australia	76	98	[e]95	100
New Zealand	65	104	37	35
Total	[r]17,918	19,813	21,271	22,628

[e] Estimate. [p] Preliminary. [r] Revised. NA Not available.

[1] In addition to the countries listed, China mainland, the German Democratic Republic, Lebanon, Vietnam, Southern Rhodesia and Yugoslavia also produced kaolin, but information is inadequate to make reliable estimates of output levels. Guatemala and Morocco each produced less than 500 tons in each of the years covered by this table.

[2] Kaolin sold or used by producers.

[3] Reported figure.

[4] Excludes unwashed kaolin.

[5] Less than 1/2 unit.

[6] Data for years ending June 30 of that stated.

Table 31.—Bentonite: World production, by country

(Short tons)

Country[1]	1976	1977	1978[p]	1979[e]
North America:				
Guatemala	[e]10	--	2,858	3,000
Mexico	61,270	65,223	37,253	40,000
United States	3,520,381	3,746,487	4,468,000	[2]4,400,000
South America:				
Argentina	145,850	126,585	131,396	160,000
Brazil	157,871	119,485	184,763	190,000
Colombia[e]	[r]1,300	[r]1,300	1,300	1,300
Peru	48,591	45,795	41,022	45,000
Europe:				
France	19,067	18,739	18,739	24,000
Greece	[r]349,178	462,363	383,182	[2]399,027
Hungary	[r]78,427	88,188	90,622	91,500
Italy	258,648	309,011	247,147	250,000
Poland[e]	55,000	55,000	55,000	55,000
Romania[e]	70,000	70,000	72,000	72,000
Spain	119,213	112,766	[e]110,000	120,000
Africa:				
Algeria (bentonitic clay)	27,022	26,896	39,313	40,000
Egypt	4,666	4,201	3,801	3,900
Morocco	[r]5,141	5,299	[e]5,300	NA
Mozambique	2,533	3,025	3,307	3,300
South Africa, Republic of	43,654	41,029	38,051	[2]50,140
Tanzania	--	39	22	22
Asia:				
Burma	1,053	1,075	1,518	1,700
Cyprus[3]	[r]5,600	14,550	15,048	15,400
Iran[e]	55,000	[r]25,800	44,100	NA
Israel (metabentonite)	[r]16,535	8,818	7,663	9,000
Japan[e]	440,000	440,000	440,000	440,000
Pakistan	823	1,200	999	1,200
Philippines	2,334	2,512	1,730	2,000
Turkey	[r]25,970	4,803	9,127	15,000
Oceania:				
Australia[4]	13,177	6,176	[e]8,300	13,000
New Zealand (processed)	1,149	1,100	1,100	1,500
Total	[r]5,524,463	5,807,465	6,463,161	6,446,969

[e]Estimate. [p]Preliminary. [r]Revised. NA Not available.

[1] In addition to the countries listed, Austria, Canada, China mainland, the Federal Republic of Germany, and the U.S.S.R. are believed to have produced bentonite, but output is not reported and available information is inadequate to make reliable estimates of output levels.

[2] Reported figure.

[3] Includes bleaching earths.

[4] Includes bentonitic clay.

Table 32.—Fuller's earth: World production, by country[1]

(Short tons)

Country[2]	1976	1977	1978[p]	1979[e]
Algeria	3,527	5,111	5,343	5,500
Argentina	3,454	4,551	3,835	4,400
Australia	[r]10	55	[e]50	55
Italy	27,402	6,993	7,700	13,200
Mexico	22,165	67,648	44,046	45,000
Morocco (smectite)	40,530	23,176	8,819	NA
Pakistan	17,637	19,842	19,842	20,000
Senegal (attapulgite)	5,100	3,753	7,639	8,000
South Africa, Republic of	--	--	264	[3]1,013
United Kingdom	[r]221,564	245,815	240,304	180,000
United States	1,341,582	1,428,326	1,530,000	[3]1,570,000
Total	[r]1,682,971	1,805,270	1,867,862	1,847,168

[e]Estimate. [p]Preliminary. [r]Revised. NA Not available.

[1] Excludes centrally planned economy countries, some of which presumably produce fuller's earth, but for which no information is available.

[2] In addition to the countries listed, France, Iran, Japan, and Turkey have reportedly produced fuller's earth in the past and may continue to do so, but output is not reported, and available information is inadequate to make reliable estimates of output levels.

[3] Reported figure.

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Bedfordshire, which is being worked by Steetley Minerals Ltd., a part of the Steetley Co. Ltd. This new site will be brought into production as the reserves at the existing deposit are depleted. In the other fuller's earth move, Robert Brett and Sons Ltd.'s application to start mining and processing at Baulking in Oxfordshire was also approved. The new greenfield plant, worked by its Brett Bentonite Ltd. subsidiary, will, if on schedule, produce about 50,000 tons per year of high-quality sodium-exchanged bentonite by midyear 1980.

In a 1979 activity, Laporte Industries Ltd. announced plans to construct a new activated fuller's earth plant at Widnes to increase its mining and processing efficiency. Laporte intended to phase out the older works at Redhill, Surrey, and a mine and small plant at Bath, Avon. An important factor in relocating the 35,000-ton-per-year plant at Widnes was the availability of surplus low-cost energy.

U.S.S.R.—The 125,000-ton-of-kaolin-per-year first phase of the Alekseyevskiy mining complex at Kokchetav went onstream in 1979. The kaolin from the complex was earmarked for both paper and ceramic uses.

TECHNOLOGY

Research carried out by the Federal Bureau of Mines at its Tuscaloosa Research Center, Tuscaloosa, Ala., has shown that waste glass recovered from municipal refuse can be used as an additive in structural clay products, as well as to produce glass wool insulation.[3] Energy savings have resulted because of lower temperatures required to melt or vitrify the product. Tentative specifications for waste glass that could be used in the production of structural clay products, such as brick, pipe, and roofing tile, were being established. In other Government research, the results of a detailed testing and evaluation program for Western bentonite on Federal lands were published. Two reports were issued, one concerned only with Montana and Wyoming,[4] and the other with the remaining Western States—Colorado, Idaho, Utah, Arizona, Nevada, California, Oregon, and Washington.[5] The studies arrived at a definitive set of specifications for a high-grade bentonite and then compared over 1,000 bentonite samples with it. The laboratory tests included apparent viscosity, water loss, pH, swelling capacity, water-soluble cations, and exchangeable sodium. The results of X-ray diffractometric, mineralogical, and stratigraphic determinations were also listed in the work. A concise update of the current bentonite production and quality control methods as practiced by industry was presented.[6] This paper also included an overview of bentonite market demands and long-range supply with resulting emphasis on changes in bentonite testing methods required to utilize existing reserves. An excellent outline for a regional approach to a clay resources appraisal stressed the blending of mineralogy and laboratory evaluation methods with the principal uses for clays.[7] The production and application of clays in captive markets, such as structural clay production, and the open market clays—china clay, ball, fire and refractory clays, bentonite, and fuller's earth—were all detailed. A laboratory method for evaluating clays, including a small-scale testing scheme, was also offered.

A compendium for active clays—bentonite, fuller's earth, sepiolite, hectorite, and attapulgite—was published.[8] This work gathers together and presents in a concise form the nomenclature—often confusing—of the palygorskite and smectite clays, their occurrences, world production, and technical appraisal of their markets. Special emphasis was afforded drilling mud, taconite, and foundry markets, including inroads made by the palygorskite (called Hormites in the work) clays in these traditional bentonite areas. Two appendices listed the world producers of these clays along with pertinent production, flowsheet, geological, and market information. Another report, similar to the above compendium, devoted to the U.S. active clay producers, was added at a later date to incorporate the more definite Bureau of Mines statistics on these clays.[9] The first part of another planned compendium, devoted solely to kaolin, stressed worldwide production and processing techniques.[10] The subtleties of new and existing kaolin processes, slurrying, and new material sources were all discussed. Of particular interest was the discussion of waterwashed kaolin processing, which detailed size classification, bleaching, ultraflotation, delamination, magnetic separation, and dewatering.

A soft mud batch dryer which significantly shortens drying time by using automatically controlled flip-flop dampers was designed to operate successfully on waste heat from brick tunnel kilns.[11] In another work, the maturity characteristics of various brick bodies and their heat work requirements were related to fuel conservation and product quality.[12] Methods for measuring heat work and its relation to body maturity are described as tools for controlling product quality.

An X-ray diffractometric method was developed which should prove valuable in not only assessing freeze-thaw resistance of brick but also detecting thermal gradients in kilns.[13] Briefly, a ratio of the line intensities of the quartz reflection at 3.34A (and/or its polymorphs) and that of the labradorite reflection at 3.2A was found to be a linear function of temperature that could be used directly to calculate firing temperatures, thermal gradients, and the porosity which influences the freeze-thaw phenomenon. The mineral-wool-fiber/clay composites, used mostly in fire-resistant acoustical ceiling systems and as thermal insulation, were found to fail predominantly by fiber pullout at less than 500° C and by fiber fracture at high temperatures (to 760° C).[14] The effectiveness of three polymeric flocculants used in distributing the clay through the low-density composites was also determined.

A sedimentary kaolin and commercial carbon black or coal, both inexpensive raw materials, were successfully reacted in a nitrogen atmosphere with an iron catalyst—either hydrous iron nitrate or chloride—below 1,450° C to yield a single phase sialon (β'-silicon nitride) material.[15] Sialons are currently being investigated as a possible new refractory material. In environment-related work, Government researchers continued determining the behavior of benzene[16] and the crystalline product of the clay-lime reaction.[17] The benzene study describes a possible harmless degradation medium. Results indicated that smectite (montmorillonite) clays saturated with aluminum (Al^{3+}) was seven times more effective than soils and three times more effective than calcium-saturated clays in sorbing benzene. In addition, volatilization was noted as a possible route for benzene loss from these systems. In the other effort, extensive X-ray diffraction crystallographic research on clay-lime, soil-lime, and fly ash-lime mixtures succeeded in identifying the major crystalline reaction product. The phase 4 $Ca0 \cdot Al_2O_3 \cdot 13H_2O$ (C_4AH_{13}) was responsible for the hardening of soil, lime, and water mixtures that is critical for effective soil stabilization.

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[1] Supervisory physical scientist, Section of Nonmetallic Minerals.

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Cobalt

By Scott F. Sibley[1]

Demand for cobalt in 1978 increased significantly compared with that of 1977. Total reported consumption of cobalt in the United States was the highest on record, at 19,994,000 pounds, and reflected a 21% increase over consumption reported for 1977. In 1979, reported consumption declined 13% compared with that of 1978.

Considerable uncertainty developed in the cobalt market with regard to future supply and price in May 1978, when African Metals Corp., the major dealer for cobalt in the United States, announced that cobalt metal orders would be accepted only on an allocation basis, beginning May 1, 1978. The allocation, still in effect at yearend 1979, was based on 70% of consumers' average monthly purchases during calendar year 1977. The uncertainty was heightened in mid-May 1978 when insurgents disrupted mining activity in Shaba Province, Zaire, the major source of the U.S. supply of cobalt. Prices soared during the last half of 1978 and stabilized in 1979.

Table 1.—Salient cobalt statistics

(Thousand pounds of contained cobalt)

	1975	1976	1977	1978	1979
United States:					
Consumption	12,787	16,482	16,577	19,994	17,402
Imports for consumption	6,608	16,487	17,548	19,029	19,998
Stocks, Dec. 31: Consumer	1,801	3,180	3,738	4,387	3,390
Price: Metal, per pound	\$3.75-\$4.00	\$4.00-\$5.40	\$5.20-\$6.40	\$6.40-\$20.00	\$20.00-\$25.00
World production, mine[1]	[r]47,600	[r]47,218	[r]48,168	55,662	62,874

[r]Revised.

[1]Based on estimated recovered cobalt.

Legislation and Government Programs.—An export reporting system for cobalt-bearing materials was established by the U.S. Department of Commerce on January 10, 1979. The Department required that exporters send to the Office of Export Administration a copy of the export declaration covering a list of specified materials (both wrought and unwrought) containing 10% or more of cobalt.

The national stockpile goal for cobalt remained at 85.4 million pounds, and the inventory in storage was 40.8 million pounds at yearend 1979.

Congress passed legislation in mid-1979 regarding sales and purchases of critical commodities in the national stockpile. The new Strategic and Critical Materials Stockpiling Revision Act opened the way for further legislation providing for sales and purchases of specific commodities. The act requires that funds from sales of stockpiled commodities be used to purchase commodities for which there is a stockpile deficit. If such purchases are not made, the funds are to revert to the Treasury after 3 years. The act also specifies that the stockpile must serve the interest of national defense only.

In November 1979, the Senate passed legislation that would restrict access to a region of cobalt mineralization northeast of the Blackbird district in Idaho. The legislation would create a "River-of-No-Return-Wilderness," a small part of which would include the zone of cobalt mineralization. Only underground mining would be permitted in the area. No action had been taken by yearend on parallel legislation in the House of Representatives.

Domestic legislation on deep seabed mining that would provide a legal framework for mining by U.S. companies was considered by committees having jurisdiction in the 96th Congress and was passed by the Senate. Voting on a final bill in the House was postponed until 1980.

DOMESTIC PRODUCTION

There was no domestic mine production of cobalt during 1978 and 1979. The single domestic refiner of cobalt, AMAX Inc. (Nickel Div.), produced about 643,000 pounds of cobalt in 1978 and 928,000 pounds in 1979 at its Port Nickel refinery in Braithwaite, La. AMAX announced on March 20, 1978, that an agreement with Botswana Concessions, Ltd. (BCL), had been signed for purchase of BCL's full output of nickel-copper-cobalt matte, one source of supply for the Louisiana refinery. Previously, the material had been toll refined. About 420 members of the United Steel Workers of America Local 8373 struck the Port Nickel refinery September 1, 1979. The strike had not been settled by yearend.

Early in 1979, Metallurgie Hoboken Overpelt, S.A., of Belgium, the world's largest processing refiner of cobalt, began construction of a plant in Laurinburg, N.C., to produce extra-fine cobalt powder to meet U.S. market requirements. The plant was planned to come onstream by mid-1980. Expected plant capacity was estimated at 1 million pounds per year of cobalt, approximately equivalent to the domestic demand for this special cobalt form.

Early in 1979, Noranda Mines, Ltd., of Canada began redevelopment of the Blackbird district of Idaho, near the town of Cobalt, about 30 miles southwest of Salmon. Since about 1893, when cobalt was first discovered in this district, cobalt has been mined intermittently by two other companies. An extensive diamond drilling program was carried out in 1979, and metallurgical tests were conducted. According to a Noranda official, exploration resulted in defining reserves of 4 million tons of ore grading 0.6% cobalt and 1.2% copper. Initial plans called for a pilot plant to concentrate 300 tons of ore per day. If the pilot operation is successful and Noranda proceeds with plans to produce 8 million pounds per year of cobalt in ore, U.S. import dependence could be reduced by as much as 30%. However, until a refining facility is built, it was expected that concentrate would be shipped overseas for refining. Last production at the pilot plant site was in 1959.

Also early in 1979, the Denver-based firm Anschutz Mining Co. purchased a property containing cobalt and associated metals near Fredericktown, Mo. The company conducted studies to determine the feasibility of reopening the former Madison cobalt-nickel-copper mine. Operations were projected to have the potential to produce 1.5 to 2 million pounds of cobalt annually, about the same quantity of nickel, and larger amounts of copper and lead. Residues from the former processing operation, containing about 2% cobalt, were shipped to Finland in late 1979 for processing to metal.

CONSUMPTION AND USES

The surge in demand in 1978 was largely the result of increased aircraft production and expanded usage of driers and catalysts. Demand also increased in tool steel, hardfacing of automobile valves, metal-cutting operations, and magnets. Demand slackened in 1979 due to high prices and substitution, especially in magnetic materials. The most significant changes in 1979 were (1) an increase in cobalt consumption for gas turbine production and (2) a decline in net-import reliance as a percent of apparent consumption. The latter resulted from an increase in the quantity of cobalt being recycled in the cemented carbide and superalloys industries. Because of price and availability concerns arising during 1978, permanent ferrite magnets gained greater acceptance in 1979 and were partly responsible for a decline in cobalt consumption in magnetic materials.

Commercial aircraft manufacturing was expected to increase significantly over the decade of the 1980's, as aging commercial airline fleets are replaced and new military aircraft are built. Obsolescence and stricter anti-noise regulations, which must be met by 1985, provided incentives to build new aircraft and engines. The growth in aircraft manufacturing was reflected in reported cobalt consumption in superalloys. At the same time, the market for turbines for powerplants, natural gas pipelines, and helicopters was strong. Limited substitution took place in 1978 and 1979, mainly of nickel-base alloys containing little or no cobalt for nickel-base alloys with higher cobalt content. Nickel-base alloys were also used as substitutes in hardfacing applications.

The largest market for cobalt was in nonmetallic applications. Use of a cobalt-molybdenum-alumina catalyst for desulfurization of light petroleum distillates was partly responsible for increased demand. In paint driers, organic cobalt compounds containing 5% to 10% cobalt were found most effective in surface drying of oil-based paints.

Table 2.—Cobalt products[1] produced and shipped by refiners and processors in the United States

(Thousand pounds)

	1978				1979			
	Production		Shipments		Production		Shipments	
	Gross weight	Cobalt content	Gross weight	Cobalt content	Gross weight	Cobalt content	Gross weight	Cobalt content
Metal	643	643	NA	NA	928	928	NA	NA
Hydrate (hydroxide)	858	531	915	567	NA	602	NA	545
Salts[2] (inorganic compounds)	9,926	2,521	10,223	2,592	NA	1,243	NA	1,209
Driers (organic compounds)	15,842	2,646	15,158	2,240	NA	1,439	NA	1,501
Total	27,269	6,341	26,296	5,399	NA	4,212	NA	3,255

NA Not available.

[1] Figures on oxide withheld to avoid disclosing company proprietary data.

[2] Various salts combined to avoid disclosing company proprietary data.

Table 3.—U.S. consumption of cobalt, by end use

(Thousand pounds of contained cobalt)

Use	Quantity	
	1978	1979
Steel:		
Stainless and heat resisting	135	137
Full alloy	250	227
High strength, low alloy	12	W
Electric	W	W
Tool	379	413
Superalloys	4,299	5,276
Alloys (excludes alloy steels and superalloys):		
Cutting and wear-resistant materials[1]	1,837	2,123
Welding materials (structural and hardfacing)	725	444
Magnetic alloys	3,768	3,266
Nonferrous alloys	590	392
Other alloys	378	274
Mill products made from metal powder	W	W
Chemical and ceramic uses:[2]		
Pigments	199	199
Catalysts	1,623	1,882
Ground coat frit	96	554
Glass decolorizer	21	43
Other	5	[3]1,791
Miscellaneous and unspecified	278	381
Total	14,595	17,402
Salts and driers: Lacquers, varnishes, paints, ink, pigments, enamels, glazes, feed, electroplating, etc	5,399	[4]NA
Grand total	19,994	17,402

NA Not available. W Withheld to avoid disclosing company proprietary data; included in "Miscellaneous and unspecified."

[1] Cemented and sintered carbides.

[2] Because of a change in reporting in 1979 from quarterly to monthly, and a change in requested statistics, figures for chemical and ceramic uses are not comparable between 1978 and 1979.

[3] Drier in paints or related usage plus feed or nutritive additive.

[4] Included separately as catalysts, ground coat frit, and other.

Table 4.—U.S. consumption of cobalt, by year and form

(Thousand pounds of contained cobalt)

Form	1975	1976	1977	1978	1979
Metal	9,202	11,706	11,547	12,823	12,006
Oxide	372	462	426	467	704
Purchased scrap	342	329	507	1,036	1,170
Other	([1])	([1])	319	269	268
Salts and driers	2,871	3,985	3,778	5,399	[2]3,254
Total	12,787	16,482	16,577	19,994	17,402

[1] Included in purchased scrap.

[2] Chemical compounds (organic and inorganic) other than oxide.

PRICES

The producer price of cobalt remained at $6.40 per pound from December 21, 1977, to February 24, 1978, when the price was raised to $6.85 per pound. On May 24, the price was raised to $8.50 per pound. Another increase, to $18, occurred September 14. On October 27, the price went to $20 per pound, where it remained through the end of the year. Zambia and Finland took the lead in raising the price in May, July, and September. The first increase, in February 1978, and the last, in October 1978, were attributed to a weakening of the U.S. dollar in relation to the Belgian franc. The other price changes reflected unusually high demand, lack of effective substitutes, and limited supply. The weighted average price for 1978 was $11.53 per pound for specification-grade cobalt metal. On February 1, 1979, the price was raised to $25 per pound, where it remained through yearend 1979. The weighted average price for 1979 was $24.58 per pound. The above prices, quoted by African Metals Corp., were f.o.b. New York or Chicago and applied to granules (shot) or broken cathodes in 551-pound (250-kilogram) drums.

Spot prices on the "free market" were as high as $55 per pound toward yearend 1978, but quantities of cobalt sold on the free market were relatively small. Some producers sold cobalt at "negotiated" prices. Spot prices in 1979 dropped from a high of $45 per pound at the beginning of the year to below the producer price at yearend. AMAX Nickel, Inc. dropped its price to $23 per pound in December 1979.

FOREIGN TRADE

In 1978, exports of unwrought cobalt metal, waste, and scrap totaled 2,153,825 pounds gross weight valued at $17,845,861. The Netherlands and the Federal Republic of Germany received the largest quantities. In 1979, U.S. exports of unwrought cobalt metal, waste, and scrap totaled 1,243,590 pounds gross weight valued at $19401,902. The Federal Republic of Germany and Japan received the largest quantities.

U.S. imports of cobalt in 1978 and 1979 are shown in tables 5 and 6.

Tariffs.—The Tokyo Round of multilateral trade negotiations was completed in 1979. Tariff rates for cobalt-containing forms at the beginning (January 1, 1980) and ending (January 1, 1987) dates of the staging period, as published in the Tariff Schedules of the United States, annotated (1980), are shown in table 7.

Table 5.—U.S. imports for consumption of cobalt, by country

(Thousand pounds and thousand dollars)

Country	Metal[1]				Oxide				Other forms[2]				Total content[3]	
	1978		1979		1978		1979		1978		1979		1978	1979
	Gross weight	Value	Gross weight	Value	Gross weight	Value	Gross weight	Value	Content	Value	Content	Value		
Australia	--	--	15	326	--	--	--	--	(4)	2	43	[5]636	(4)	58
Belgium-Luxembourg	2,365	29,985	1,777	47,161	1,048	8,841	452	8,275	184	1,801	95	1,962	3,325	2,206
Botswana	--	--	--	--	--	--	--	--	770	[5]5,328	358	[5]5,273	770	358
Canada	1,295	13,703	870	23,336	16	157	--	--	(4)	3	8	114	1,307	878
Finland	855	9,049	1,154	30,372	--	--	--	--	2	26	1	14	857	1,155
France	413	3,464	537	9,431	--	--	--	--	1	17	(4)	1	414	537
Germany, Federal Republic of	190	1,815	159	3,538	--	--	14	297	(4)	1	(4)	40	190	169
Japan	430	3,821	672	18,432	5	69	4	101	3	22	--	--	437	675
Netherlands	46	218	146	5,268	1	5	11	346	(4)	(4)	--	--	47	154
New Caledonia	--	--	--	--	--	--	--	--	222	[5]1,536	103	[5]1,525	222	103
Norway	616	6,070	927	26,780	--	--	--	--	--	--	--	--	616	927
South Africa, Republic of	--	--	16	405	--	--	--	--	543	[5]3,758	123	[5]1,815	543	139
United Kingdom	225	2,318	236	5,972	4	68	2	62	10	76	--	59	238	244
Zaire	7,872	77,642	8,784	205,367	--	--	22	348	--	--	--	--	7,872	8,801
Zambia	2,134	18,980	3,538	84,699	--	--	--	--	--	--	--	--	2,134	3,538
Other	47	597	56	1,163	3	50	--	--	9	55	--	3	58	56
Total[6]	16,488	167,662	18,887	462,250	1,077	9,190	505	9,429	1,744	12,625	738	11,441	19,029	19,998

[1] Includes unwrought metal and waste and scrap.

[2] Contained cobalt in nickel-copper and nickel matte from Australia, Botswana, New Caledonia, and the Republic of South Africa. Salts and compounds were imported from the remaining countries.

[3] Estimated contained cobalt.

[4] Less than 1/2 unit, contained metal.

[5] Based on weighted average cobalt metal price of $11.53 per pound for 1978 and $24.58 per pound for 1979, multiplied by 0.6 (estimated factor for matte) for imports from Australia, Botswana, New Caledonia, and the Republic of South Africa.

[6] Data may not add to totals shown because to independent rounding.

Table 6.—U.S. imports for consumption of cobalt, by class

(Thousand pounds and thousand dollars)

Class	1977	1978	1979
Metal:[1]			
Gross weight	16,833	16,488	18,887
Cobalt content[e]	16,833	16,488	18,887
Value	$91,381	$167,662	$462,250
Oxide:			
Gross weight	506	1,077	505
Cobalt content[e]	374	797	373
Value	$2,346	$9,190	$9,429
Salts and compounds:			
Gross weight	246	696	370
Cobalt content[e]	74	209	111
Value	$381	$2,003	$2,192
Other forms:[2]	267	1,535	627
Value	[r]$895	$10,622	$9,249
Total content	[r]17,548	19,029	19,998

[e] Estimate. [r] Revised.

[1] Includes unwrought metal and waste and scrap.

[2] Contained cobalt in nickel-copper and nickel matte.

Table 7.—U.S. import duties

Tariff item	Tariff number	Most Favored Nation (MFN)		Non-MFN
		Jan. 1, 1980	Jan. 1, 1987	Jan. 1, 1980
Ore and concentrate	601.18	Free	Free	Free
Unwrought metal, waste and scrap	632.20	Free	Free	Free
Alloys, unwrought	632.86	9% ad valorem	9% ad valorem	45% ad valorem
Chemical compounds:				
Oxide	418.60	1.2 cents/lb.	1.2 cents/lb.	20 cents/lb.
Sulfate	418.62	1.4% ad valorem	1.4% ad valorem	6.5% ad valorem
Other	418.68	5.8% ad valorem	4.2% ad valorem	30% ad valorem

WORLD REVIEW

International.—Further attempts were made in 1978 and 1979 to arrive at an international agreement on deep sea mining. An Eighth Session of the Third United Nations Conference on the Law of the Sea was held in New York in 1979. A Ninth Session was scheduled for Geneva in 1980.

Australia.—Freeport Queensland Nickel, Inc., reported early in 1979 that the Greenvale project it jointly operated with Metals Exploration Queensland, Pty., Ltd. (MEQ), had been financially restructured. Under the new arrangements, the minimum debt service was lowered. Cobalt became increasingly important to the operation. As a result of the rapid rise in price, sales of cobalt accounted for about one-third of Greenvale's income during the last half of 1978. Production of cobalt contained in mixed sulfide concentrate in 1979 was more than 1.9 million pounds. The increased output was achieved by selectively mining pockets of ore relatively high in cobalt, and by bringing the Yabulu treatment plant located near Townsville, Queensland, up to design capacity. The output, containing 13% to 16% cobalt, was shipped to Nippon Mining Co. in Japan for refining.

Canada.—INCO, Ltd., reportedly planned to double its cobalt output over that of 1977, but implementation was to be spread out over several years. The increase was to be achieved by a slight change in process and by modification in the handling of slag. INCO's production of cobalt was limited in 1978 and 1979 by a labor strike at the company's Sudbury, Ontario, operations.

Sherritt Gordon Mines, Ltd., announced at midyear 1978, that it had entered into a long-term agreement with INCO to purchase nickel feed material for its Fort Saskatchewan, Alberta, refinery. This material was to partially replace the nickel-cobalt concentrate formerly purchased from two Australian mines and from Sherritt's Lynn Lake mine, which was closed in 1976.

The feed was diverted to Sherritt from INCO's Thompson, Manitoba, refinery, where cobalt oxide is produced.

Falconbridge Nickel Mines, Ltd., announced plans in 1978 to purchase nickel-cobalt matte for custom refining at its Kristiansand, Norway, plant. This refinery has a capacity to produce 2 million pounds of cobalt per year. Falconbridge also announced in late 1978 that it was suspending use of a price list for cobalt and negotiating price according to market requirements.

Noranda Mines, Ltd., reportedly planned to finance extensive exploration for cobalt near the town of Cobalt, Ontario, about 75 miles north of North Bay. The properties to be explored are controlled by Agnico Eagle Mines, Ltd. If the exploration proves successful, refining facilities costing up to $8 million reportedly would be built by Noranda in exchange for a 49% share of the profits from cobalt sales. About 4 million pounds of cobalt had been produced as a byproduct of silver mining in the cobalt area over the previous 25 years.

Finland.—Outokumpu Oy, Finland's State-owned cobalt producer, increased its production capacity at Kokkola from about 1,000 short tons of refined metal per year to about 1,500 short tons in 1979, at a cost of $12 million. Cobalt was produced in Finland mostly as a byproduct of copper production. However, some feedstock for new production was cobalt residues that originated in the German Democratic Republic. More than half of the new material (about 300 tons) was planned to be extra-fine cobalt powder, but technical problems delayed production of this form until 1980. Plans also included production of cobalt sulfate.

France.—Société Métallurgique Le Nickel (SLN) announced in December 1979 that production of nickel and cobalt had resumed at its Sandouville electrolytic refinery near Le Havre. The new refinery was shut down for about 1 year after a serious fire in late 1978. Annual production was expected to be about 6,500 metric tons of nickel and 450 tons of cobalt in cobalt chloride. This was approximately 40% of French cobalt consumption. Feed for the plant was provided by nickel-cobalt matte from SLN in New Caledonia.

Germany, Federal Republic of.—In mid-1979, the Government of the Federal Republic of Germany announced a plan for stockpiling strategically important metals, including chromium, cobalt, and manganese. It was planned that purchases for the stockpile would be made by industrial users over a 5-year period and financing would be obtained from a $200 million fund established by the central bank of the Federal Republic of Germany.

Indonesia.—The consortium P.T. Pacific Nikkel Indonesia reportedly planned further exploratory drilling of nickel-cobalt deposits on Gag Island, west of Irian Java. Initial production had been planned for 1983-84, and the total cost was estimated at $1 billion. However, development was deferred indefinitely early in 1979 because of the escalating capital costs and uncertain nickel market.

Japan.—According to the Japanese Ministry of International Trade and Industry, Japanese cobalt consumption in 1978 totaled about 5.3 million pounds. Japan's consumption of cobalt, by end use, was as follows (in thousand pounds): Superalloys and tool steel (930); magnetic materials (2,570); cemented carbides (250); catalysts (254); and others (1,264). The two new refineries of Sumitomo Metal Mining Co. and Nippon Mining Co. operated at near capacity level. Total Japanese production of cobalt in 1979 was 5.7 million pounds.

New Caledonia.—AMAX Inc. and the Bureau de Rechérche Géologiques et Minières of France planned to produce 1,100 short tons per year of cobalt and 22,000 to 33,000 short tons per year of nickel from a proposed project in northern New Caledonia, where a high-grade garnierite deposit is located. The operation would use a patented hydrometallurgical process developed by AMAX and would use sulfur as an energy source. No date was set for construction of the proposed project, but feasibility studies were expected to take 2 to 3 years.

Philippines.—In 1978, Marinduque Mining and Industrial Corp. reportedly signed a 10-year contract with Sumitomo Metal Mining Co. of Japan for the refining of mixed nickel-cobalt concentrate produced at Marinduque's Nonoc Island facility. The mixed sulfide contained about 10% cobalt and 30% to 35% nickel. Under the new contract arrangements, 50 tons of metal per month was to be toll refined and returned to Marinduque for marketing.

South Africa, Republic of.—In 1978, cobalt-bearing nickel-copper matte produced by Rustenburg Platinum Mines, Ltd., was shipped to Braithwaite, La., for refining by AMAX Inc. In mid-1979, Rustenburg brought onstream a plant to produce cobalt sulfate. The new plant made the Republic of

South Africa self-sufficient in cobalt and was expected to permit exports of cobalt sulfate in 1980. South African consumption is estimated at 150,000 pounds of cobalt metal annually.

Uganda.—The Kilembe Mines, Ltd., reportedly had stockpiled over about a 20 year period more than 1 million tons of pyrite tailings at Kasese in southwest Uganda, where a concentrator is located. Cobalt content averages about 1.4%. The tailings were produced from the processing of copper ore. The Ugandan Government reportedly was considering construction of a refinery at Kasese to recover cobalt, copper, and nickel.

United Kingdom.—About 600 workers at INCO's nickel-cobalt refinery at Clydach, Wales, struck the facility October 17, 1979. The strike had not been resolved at yearend.

Zaire.—The Zairian marketing organization, Société Zairoise de Commercialization (SOZACOM) announced in early May 1978 that it was reducing allocations of cobalt to clients worldwide by about 30%. This resulted from a surge in demand, declining production due to a depressed copper market, and inefficient recovery of cobalt from the copper ores.

The most publicized event of 1978 was the invasion in mid-May of the mining town of Kolwezi in Shaba Province, the major source for the U.S. supply of cobalt. Insurgents disrupted cobalt and copper mining and refining, and most expatriate technical personnel were evacuated. Following reoccupation of the town by government forces, production of cobalt resumed.

In June 1978, Générale des Carrières et des Mines (GECAMINES), the State-owned mining company, obtained a $100 million emergency loan from the International Monetary Fund (IMF), and early in September 1979, the IMF reportedly approved a standby line of credit to Zaire of $153 million, to be used in support of the Government's economic stabilization program. In addition, the World Bank and the Libyan Arab Bank reportedly loaned Zaire $460 million to complete its 4-year P-2 expansion plan. Under this plan, about 13 million pounds per year of cobalt production capacity was to be added to the existing 35 million pounds capacity by opening the new Mashamba and Dikuluwe open pit mines by 1981. These would supply 5 million tons of ore per year to the Dima concentrator under construction in Kolwezi. The entire complex could be completed in 1983 or 1984.

In July 1979, a group of countries and organizations, including the EEC and Arab Bank for Economic Development reportedly pledged $30 million to Zaire, Zambia, and Angola to modernize the Benguela Railway through Angola. The line had been closed since August 15, 1975, because of political and military difficulties. Completion of the first stage of the project was to take 6 to 9 months.

Zambia.—Cobalt production capacity in 1979 was approximately doubled by an expansion at Roan Consolidated Mines, Ltd. (RCM), which opened a cobalt production plant at Chambishi to process concentrates formerly shipped to Nchanga Consolidated Copper Mines, Ltd. (NCCM). The new leaching plant had an initial capacity of 2,000 to 2,500 tons, bringing total Zambian capacity up to a minimum of 4,200 tons of cobalt annually. Zambia Industrial and Mining Corp., Ltd. (ZIMCO), a State-owned company, held 51% interest in RCM. Other shares were held by AMAX Inc. (20%) and Security Nominees, Ltd. (12%). ZIMCO also acquired 60% interest in NCCM in October, increasing its equity participation from 51%.

In 1978, Zambian officials reported discovery of a significant cobalt-bearing ore body on the western lip of the Chingola open pit copper mine of NCCM. Resources were reported to be about 165,000 tons of cobalt. NCCM also received a loan in 1979 to finance a $155 million expansion of its facilities at Rokana. Plans called for modification of the existing concentrator for the production of copper-cobalt concentrates (previously, no cobalt was being recovered from the Rokana copper concentrates). A new cobalt plant was also planned. The new plant was expected to have an annual capacity of 2,500 tons of cobalt and was expected to be in production by the end of 1985. Immediate expansion plans being carried out by NCCM at Rokana were expected to add about 400 tons to the facility's rated annual capacity of 2,200 tons per year. Expansions underway in Zambia, considered together (and including the Chambishi expansion), were expected to bring capacity up to 5,000 tons by the end of 1980.

Zimbabwe-Rhodesia.—Cobalt concentrates were being produced for the first time in Zimbabwe-Rhodesia as a byproduct of nickel mining. Exports of concentrates were estimated to be about 40 tons per month.

Table 8.—Cobalt: World production, by country

(Short tons)

Country	Mine output, metal content[1]				Metal[2]			
	1976	1977	1978[p]	1979[e]	1976	1977	1978[p]	1979[e]
Australia[3]	[r]600	1,100	1,500	1,700	--	--	--	--
Botswana	[r]145	182	298	300	(4)	(4)	--	--
Canada[5]	[r]1,495	1,637	1,360	[e]1,522	328	506	572	600
Cuba[e]	1,800	1,800	1,800	1,900	--	--	--	--
Finland	[r]1,409	1,358	1,429	1,320	983	1,086	1,016	[e]1,286
France[7]	--	--	--	--	799	818	960	795
Germany, Federal Republic of	--	--	--	--	276	386	[e]330	365
Japan	--	--	--	--	568	1,205	2,065	[e]2,866
Morocco	[r]1,090	1,119	1,250	1,000	--	--	--	--
New Caledonia[8]	90	120	170	230	--	--	--	--
Norway	--	--	--	--	635	777	575	751
Philippines	[r]542	1,195	1,318	1,430	--	--	--	--
U.S.S.R.[e]	2,000	2,100	2,150	2,000	2,000	2,100	2,150	2,000
United Kingdom[9]	--	--	--	--	760	[r]860	560	500
United States	--	--	--	--	182	244	322	[e]464
Zaire	[e]12,100	[e]11,600	[e]14,660	16,535	11,779	11,252	14,468	16,000
Zambia	2,398	1,878	1,911	3,500	2,398	1,878	1,726	3,100
Total	[r]23,669	[r]24,064	27,831	31,437	[r]20,708	21,112	24,734	28,721

[e]Estimate. [p]Preliminary. [r]Revised.

[1] Figures presented represent recovered cobalt content. In addition to the countries listed, Bulgaria, Cyprus, the German Democratic Republic, Greece, Indonesia, Poland, the Republic of South Africa, Southern Rhodesia, Spain, and Uganda are known to produce nonferrous metal ores that contain cobalt. Information is inadequate for formulation of reliable estimates of output levels. Other copper and/or nickel producing nations neither listed in the body of the table nor in the preceding part of this footnote also may produce ores containing cobalt as a byproduct component, but recovery is small or nil.

[2] Figures presented represent elemental metallic cobalt recovered unless otherwise specified. In addition to the countries listed, Czechoslovakia presumably recovers cobalt from Cuba. Belgium, which in recent years has imported small quantities of partly processed materials containing cobalt, may continue to recover cobalt from such materials, but output is not reported, and available general information is inadequate for formulation of reliable estimates of output levels.

[3] Data series on mine output revised from previous editions to an estimate that represents only the part of total production that is actually recovered. Australia does not report any production of metallic cobalt, but does produce intermediate metallurgical products (cobalt oxide and nickel-cobalt sulfide), with cobalt contents as follows in short tons: 1976-978; 1977-916; 1978-1,296; 1979-Not available.

[4] Revised to zero.

[5] Actual output is not reported. Data for mine output are total cobalt content of all products derived from ores of Canadian origin, including nickel oxide sinter shipped to the United Kingdom for further processing, and nickel-copper-cobalt matte shipped to Norway for further processing. Data presented for metal output represent the output within Canada of metallic cobalt from ores of both Canadian and non-Canadian origin.

[6] Reported figure.

[7] Production as reported in Annuaire 1978 de Statistique Industrielle, p. 61. Annuaire Minemet Group I metal 1978, p. 44, gives the following figures, in short tons: 1976-78: 946, 939, 998. Presumably the difference between the foregoing figures and those presented in the body of the table represent cobalt recovery in intermediate metallurgical products and/or in compounds.

[8] Series revised to reflect estimated actual recovery from ores and intemediate metallurgical products exported from New Caledonia to Japan, France, and the United States. The previously reported qunatity either: 1) is among the waste materials of ore concentrating and smelting processes or 2) is included in nickel-cobalt products. The estimated content of total ores mined is as follows, in short tons: 1976-569; 1977-4,497; 1978-2,535; 1979-Not available.

[9] Estimated recovery of elemental cobalt and cobalt in compounds from intermediate metallurgical products originating in Canada.

TECHNOLOGY

The Bureau of Mines continued research on extraction of cobalt from laterites in Oregon, the Duluth gabbro in Minnesota, lead ores in Missouri, and deep sea manganese nodules. In 1978, a $2.3 million cost-sharing agreement for demonstration-plant testing of a process to extract nickel and cobalt from abundant but low-grade laterite deposits in Oregon and northern California was signed by the Bureau and the Mineral Sciences Division of UOP Inc. Test runs were scheduled to begin in May 1980 at the UOP pilot plant in Tucson, Ariz. The process to be tested includes roasting to remove sulfur, followed by treatment with carbon monoxide at a temperature between 550° and 650°C. An oxidizing ammonia-ammonium sulfate leach with solvent extraction and electrolytic deposition recovers cobalt and nickel separately. At the Bureau's Twin Cities Research Center, recovery of cobalt by flotation, from ore containing about 0.01% cobalt, was studied.

At the Rolla Research Center, experiments were conducted to determine how cobalt and nickel could be concentrated by the beneficiation of middlings and tailings produced from lead ores. Also, recovery of nickel and cobalt from residues generated by the smelting of lead concentrate was reported[2] and a report was published on recovery of cobalt as a byproduct of lead mining.[3] The Salt Lake City Research Center continued research on a metallurgical process for recovering manganese, cobalt, and other metals from seabed nodules, which contain about 0.35% cobalt. In 1979, an investigation was begun on recovery of cobalt from high-arsenic sulfide ores of the Blackbird district in Idaho.

At the Reno Research Center, investigations continued on mischmetal alloys containing cobalt, copper, magnesium, and iron, for use in permanent magnets in place of samarium-cobalt alloys. By substituting copper and magnesium for a portion of the cobalt, magnetic properties were considerably enhanced.[4]

Technical developments by jet engine manufacturers that may result in greater fabrication efficiency for cobalt-bearing alloys in gas turbines included hot isostatic pressing (HIP), which eliminates a forging step in making disk blanks for aircraft engines from powdered metal. Homogeneous parts are produced with a raw-materials-to-end product ratio (the" buy-to-fly ratio") of about 2.5 to 1, compared with a 5 to 1 or 6 to 1 ratio for conventional methods.[5] In addition, the Rapid Solidification Rate (RSR) technique and use of single-crystal blades in gas turbines received considerable attention.

A producer and consumer of magnet alloys developed a new alloy called "Chromindur" that may reduce cobalt usage by 15% and cut the manufacturing cost of magnets used in standard ring-armature type telephone receivers.[6]

A specialty alloy producer developed a cobalt-free tool steel with properties that are claimed to equal or exceed those of the cobalt-bearing types. The new alloy was developed to replace high-speed steels used to machine materials that generate extremely high temperatures at the cutting edge. Although this new alloy was designed to replace the standard T-15 cobalt-containing alloy, another cobalt-free alloy was tested that was expected to replace the more widely used M-42 type. It was expected that the latter alloy could be used for machining where heavy cuts are required at high speeds and feeds, and for cutting hard and abrasion-resistant material.[7]

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[1] Physical scientist, Section of Ferrous Metals.

[2] Sandburg, R. G., T. L. Hebble, and D. L. Paulson. Oxidative Sulfuric Acid Leaching of Lead Smelter Mattes. BuMines RI 8371, 1979, 16 pp.

[3] Clifford, R. K., and L. W. Higley, Jr. Cobalt and Nickel Recovery From Missouri Lead Belt Chalcopyrite Concentrate. BuMines RI 8321, 1978, 14 pp.

[4] Walkiewicz, J. W., and M. M. Wong. Magnetic Properties of Mischmetal (Co, Cu, Fe, Mg) Alloys. IEEE Trans. on Magnetics, MAG 15, No. 6, November 1979, pp. 1757-1759.

[5] Lupi, R. D. Superalloy Jet Parts Cut Waste Costs. Am. Metal Market, v. 86, No. 80, Apr. 25, 1978, p. 18.

[6] Iron Age. Magnetic Alloy is Cold Stampable. V. 221, No. 7, Feb. 14, 1978, p. 53.

[7] Obrzut, J. J. New Super High-Speed Steel Contains No Cobalt. Iron Age. v. 223, No. 2, Jan. 14, 1980, pp. 46-47.

Columbium and Tantalum

By Thomas S. Jones[1]

All columbium and tantalum raw materials were imported in 1978-79; none were mined domestically nor were any released from Government stockpiles. Columbium raw materials were imported mainly as mineral concentrates. Tin slags, including materials derived from tin slags, continued to be the largest component of tantalum supply. Nearly all columbium materials imported were for domestic consumption, whereas a significant amount of tantalum was exported in upgraded form. Trade in columbium materials was at a deficit of $27 million in 1978 and $39 million in 1979; for tantalum materials, there were surpluses of $13 and $22 million in 1978 and 1979, respectively.

Prices escalated almost continuously for tantalum raw materials and products amidst expressions of concern about status of the world tantalum supply. The contract price for Canadian tantalite, a major source of tantalum for the United States, rose from $24 per pound of contained pentoxide at the start of 1978 to $75 by the end of 1979. Spot tantalite prices increased by an even greater amount. Columbite prices also rose significantly with most of the increase occurring in 1979, when prices more than doubled; high-purity ferrocolumbium prices followed a similar pattern. In contrast, the price of ferrocolumbium for steelmaking was unchanged throughout 1978 and the first half of 1979, after which the price was advanced a relatively modest amount.

Usage of columbium as ferrocolumbium by the steel industry and of tantalum by the electronics industry continued to dominate the respective consumption patterns. Increasing consumption of columbium as ferrocolumbium and nickel columbium resulted in successive records for overall columbium consumption, 5.7 million pounds in 1978 and 6.3 million pounds in 1979. In both years, rising demand for columbium in superalloys contributed significantly to consumption increases. Likewise, continued strong demand for tantalum produced greater shipments by domestic processors in both 1978 and 1979. At the same time, higher tantalum prices resulted in some substitution away from tantalum, intensified tantalum recycling in carbides, and stimulated a more widespread search for and development of sources of tantalum supply worldwide.

Legislation and Government Programs.—Changes in U.S. Government inventories of columbium and tantalum materials consisted of only insignificant bookkeeping adjustments in 1978. There were neither acquisitions nor sales of stockpile excesses, and goals remained the same. As shown in table 3, most of the goal for columbium concentrates was met under the offset concept, while inventories of all tantalum materials continued to be considerably below the respective goals.

The U.S. Environmental Protection Agency issued a report in 1979 on liquid wastes and procedures for control thereof as developed in a study that included domestic firms engaged in primary production of columbium and tantalum salts and metal. This information was preliminary to the setting of control standards.[2]

Table 1.—Salient columbium statistics

(Thousand pounds)

	1975	1976	1977	1978	1979
United States:					
Mine production of columbium-tantalum concentrates	--	--	--	--	--
Releases from Government excesses (Cb content)[1]	463	70	--	[2]1	--
Consumption of raw materials (Cb content)	[r]1,755	[r]2,722	[r]2,427	2,073	2,402
Production of primary products:					
Columbium metal (Cb content)	W	W	W	W	W
Ferrocolumbium (Cb content)	[e]985	1,565	1,455	1,566	969
Consumption of primary products:					
Columbium metal (Cb content)	130	291	W	W	W
Ferrocolumbium, nickel columbium, and other columbium materials (Cb and Ta content)	3,348	3,389	4,389	5,694	6,337
Exports: Columbium metal, compounds, and alloys (gross weight)	53	67	75	[e]95	[e]100
Imports for consumption:					
Mineral concentrate (Cb content)[e]	845	2,201	1,551	1,962	1,690
Columbium metal and columbium-bearing alloys (Cb content)	3	([3])	2	([3])	[e]4
Ferrocolumbium (Cb content)[e]	1,947	2,221	2,676	4,159	5,515
Tin slags (Cb content)[4]	144	296	880	[5]436	[e]1,133
World: Production of columbium-tantalum concentrates (Cb content)[e]	17,324	[r]20,903	19,402	[p]21,263	[e]22,714

[e] Estimate. [p] Preliminary. [r] Revised. W Withheld to avoid disclosing company proprietary data.

[1] Includes columbium content in raw materials from which columbium is not recovered and material released as payment-in-kind for upgrading.

[2] Net change in inventory report.

[3] Less than 1/2 unit.

[4] Receipts reported by consumers; includes synthetic concentrates and other miscellanous materials in 1977-79.

[5] After deduction of reshipments.

Table 2.—Salient tantalum statistics

(Thousand pounds)

	1975	1976	1977	1978	1979
United States:					
Mine production of columbium-tantalum concentrates	--	--	--	--	--
Releases from Government excesses (Ta content)[1]	87	8	[2]([4])	[2]1	--
Consumption of raw materials (Ta content)	[r]766	[r]1,485	[r]1,448	1,571	1,740
Production of primary metal (Ta content)	[r]461	[r]1,089	[r]678	[r]974	NA
Consumption of primary products:					
Tantalum metal (Ta content)	450	1,098	732	978	NA
Exports:					
Tantalum ore and concentrate (gross weight)	60	59	118	64	[3]329
Tantalum metal, compounds, and alloys (gross weight)	471	367	470	686	426
Tantalum and tantalum alloy powder (gross weight)	161	219	234	211	296
Imports for consumption:					
Mineral concentrate (Ta content)[e]	631	827	657	596	680
Tantalum metal and tantalum-bearing alloys (Ta content)	66	52	[r]126	137	144
Tin slags (Ta content)[4]	236	431	1,275	[5]676	[5]1,140
World: Production of columbium-tantalum concentrates (Ta content)	[e]906	[r]749	905	[p]764	[e]855

[e] Estimate. [p] Preliminary. [r] Revised. NA Not available.

[1] Includes material released as payment-in-kind for upgrading.

[2] Net change in inventory report.

[3] Includes reexports.

[4] Receipts reported by consumers; includes synthetic concentrates and other miscellanous materials in 1977-79.

[5] After deduction of reshipments.

Table 3.—Columbium and tantalum materials in Government inventories as of Dec. 31, 1979

(Thousand pounds of columbium or tantalum content)

Material	Stockpile goals	National (strategic) stockpile	Defense Production Act (DPA) inventory	Supplemental stockpile	Total
Columbium:					
Concentrates	3,131	[1]1,780	--	--	[2]1,780
Carbide powder	--	21	--	--	[3]21
Ferrocolumbium	--	[3]931	--	--	[3]931
Metal	--	45	--	--	[3]45
Tantalum:					
Minerals	5,452	[4]2,551	--	--	2,551
Carbide powder	889	29	--	--	29
Metal	1,650	[5]201	--	--	201

[1] Includes 869,000 pounds of non-stockpile-grade material.
[2] All surplus columbium carbide powder, ferrocolumbium, and columbium metal were used to offset columbium concentrates shortfall. Total offset = 1,173,000 pounds.
[3] Includes 333,000 pounds of non-stockpile-grade material.
[4] Includes 1,152,000 pounds of non-stockpile-grade material.
[5] Includes negligible quantity of non-stockpile-grade material.

DOMESTIC PRODUCTION

No domestic mineral production of either columbium or tantalum was reported again in either 1978 or 1979. A small quantity of domestic concentrate was reported shipped in 1979, evidently from existing mine stockpiles. Rising tantalum prices renewed interest in low-grade domestic sources, including a proposed dredging operation in Idaho.

Domestic production of ferrocolumbium, expressed as contained columbium, rose 8% in 1978 but declined 32% in 1979. In both years, value of ferrocolumbium production was an estimated $17 million, a reflection of a trend to predominance of high-purity ferrocolumbium in the production mix and, to a lesser extent, price advances for the high-purity grade.

Tantalum content of raw materials consumed by processors in production of tantalum compounds and metal was 1,571,000

Table 4.—Major domestic columbium and tantalum processing and producing companies in 1978-79

Company	Plant location	Products[1] Metal[2] Cb	Metal[2] Ta	Carbide Cb	Carbide Ta	Oxide/salts Cb	Oxide/salts Ta	FeCb and/or NiCb
Cabot Corp.								
Kawecki Berylco Industries, Inc	Boyertown, Pa	X	X	--	X	X	X	--
Do	Revere, Pa	--	--	--	--	--	--	X
Kennametal, Inc	Latrobe, Pa	X	X	X	X	--	X	--
Mallinckrodt, Inc	St. Louis, Mo	--	--	--	--	X	X	--
Metallurg, Inc.								
Refractory Metals, Inc	Houston, Tex	--	--	--	X	--	--	--
Shieldalloy Corp	Newfield, N.J	--	--	--	--	--	--	X
NRC Inc.[3]	Newton, Mass	--	X	--	--	--	--	--
Pesses Co., The	Newton Falls, Ohio	--	--	--	--	--	--	X
H.K. Porter Co., Inc.								
Fansteel, Inc	Muskogee, Okla	X	X	--	X	X	X	--
Do	North Chicago, Ill	--	X	--	--	--	--	--
Reading Alloys, Inc	Robesonia, Pa	--	--	--	--	--	--	X
Teledyne Inc.,								
Teledyne Wah Chang Albany Div.	Albany, Oreg	X	X	--	X	X	X	X

[1] Cb, columbium; Ta, tantalum; FeCb, ferrocolumbium; NiCb, nickel columbium.
[2] Includes miscellaneous alloys.
[3] Jointly owned by South American Consolidated Enterprises, S.A., and H. C. Starck Berlin.

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pounds in 1978 and 1,740,000 pounds in 1979. In addition, processors reported consumption of about 50,000 pounds of purchased scrap in each year.

Plant operations which were expanded by Fansteel, Inc., in 1978-79 included the liquid-liquid digestion facilities at the Muskogee, Okla., plant and wire- and tube-making equipment at the North Chicago, Ill., plant. Expansion of sodium reduction operations was also begun at Muskogee, to be completed in 1980.

Kawecki Berylco Industries, Inc. (KBI), ownership of which in 1977 had passed from Molycorp, Inc., to Union Oil Co. of California, was merged in 1978 into Cabot Corp. as a wholly owned subsidiary following Cabot's purchase of all KBI stock for $96 million. In 1979 KBI joined Hudson Bay Mining and Smelting Co., Ltd., in exploration for mineral deposits worldwide, including those containing columbium and tantalum.

CONSUMPTION, USES, AND STOCKS

Reported consumption of ferrocolumbium and nickel columbium continued to advance, resulting in overall columbium consumption totals of 5.7 million pounds in 1978 and 6.3 million pounds in 1979, both of which were record quantities. Ferrocolumbium and nickel columbium were still almost entirely consumed in the manufacture of steel and superalloys. Both end-use sectors had a substantially higher demand for columbium additives in 1978 than for the previous year; total columbium usage was up 30%. Columbium consumption rose a comparatively modest 11% in 1979, mainly on the strength of a demand for columbium in superalloys half again as great as that in 1978. The demand for columbium in superalloys in 1979 even surpassed that for columbium in high-strength, low-alloy (HSLA) steel, and raised consumption of columbium as nickel columbium from over 200,000 pounds in 1978 to over 600,000 pounds in 1979. In steelmaking, the 1979 totals for raw steel production and overall columbium usage hardly changed from those in 1978. The strongest increase in consumption for any steelmaking end use in 1979 was that in HSLA steel, which was higher by 8%.

Columbium-bearing HSLA steels were among the steels considered by the automotive industry for replacing conventional carbon steels in order to save weight. In some instances, development of suitable technology to overcome forming or welding problems was necessary. Not all automotive applications of HSLA steel, also more simply termed high-strength steel, favored expanded usage of columbium. Columbium was of relatively little significance in dual-phase steels, which were among the newer of the many alternatives.

Columbium continued to be used as a minor alloying constituent in pipeline and other tubular steels. Emerging alloying applications for columbium included its use in a HSLA bar steel, in a plate steel for pressure vessels and low-temperature applications, in the larger sizes of concrete reinforcing bar, and in a titanium-base alloy for deep-sea submersibles. The amount of columbium being consumed in various superconductor materials was growing, and aircraft fasteners were being made from a columbium-titanium alloy having a composition similar to superconductor alloys.

In tantalum, rapidly escalating prices put the economics of each use under intense scrutiny; nevertheless, overall shipments grew 6% from 1977 to 1978 and 12% from 1978 to 1979, according to data of the Tantalum Producers Association. For both 1978 and 1979, the quantity of powder and anodes shipped as well as the number of capacitors manufactured were up compared with those of the previous year. Computer, automotive, and military applications of capacitors were expanding even as tantalum was being eliminated from consumer electronics. In 1979, Union Carbide Corp.'s Electronics Division announced the start of a major tantalum capacitor plant at Greenwood, S.C., that was to be operational within a year. In the same year, Plessey Capacitors, Inc., with a parent in the United Kingdom, formed a tantalum division at its California site for manufacturing capacitors for missile and aerospace applications. Next to capacitors, cemented carbides remained the most important end use of tantalum. Conservation of tantalum usage in carbides was being promoted through development of alternative compositions and wider recycling of carbide scrap.

Aggregate stocks of columbium and tantalum raw materials reported by processors and dealers for yearend 1978 contained 3,440,000 pounds of columbium and 3,062,000 pounds of tantalum. The corresponding data for yearend 1979 were 4,284,000 pounds of columbium and 2,753,000 pounds of tantalum. Compared with the previous year, yearend stocks of columbium raw materials were up slightly in 1978 and substantially higher in 1979. Yearend stocks of tantalum raw materials declined about 8% in each year. Tin slags were the largest component of raw material inventories for both columbium and tantalum, especially the latter.

Table 5.—Reported shipments of columbium and tantalum materials

(Pounds of metal content)

Material	1978	1979	Change (percent)
Columbium products:			
Compounds, including alloys	1,611,000	1,627,800	+1
Metal, including worked products	223,700	329,500	+47
Other	12,500	64,200	+414
Total columbium	1,847,200	2,021,500	+9
Tantalum products:			
Oxides and salts	38,200	35,400	-7
Alloy additive	4,400	23,700	+439
Carbide	116,900	190,100	+63
Powder and anodes	840,000	928,200	+10
Ingot (unworked consolidated metal)	7,200	6,600	-8
Mill products	321,900	365,200	+13
Scrap	184,100	151,000	-18
Other	2,100	--	--
Total tantalum	1,514,800	1,700,200	+12

Source: Tantalum Producers Association.

Table 6.—Consumption, by end use, and industry stocks of ferrocolumbium and nickel columbium in the United States

(Pounds of contained columbium)[1]

End use	1978	1979
Steel:		
Carbon	1,385,038	1,425,132
Stainless and heat-resisting	805,100	827,801
Full alloy	655,527	505,084
High-strength, low-alloy	1,626,248	1,753,172
Electric	--	(2)
Tool	(2)	(2)
Unspecified	10,258	11,935
Total steel	4,482,171	4,523,124
Superalloys	1,145,778	1,776,880
Alloys (excluding alloy steels and superalloys)	59,909	31,932
Miscellaneous and unspecified	6,474	5,398
Total consumption	5,694,332	6,337,334
Stocks, Dec. 31:		
Consumer	W	W
Producer[3]	W	W
Total stocks	1,256,000	1,614,000

W Withheld to avoid disclosing company proprietary data.

[1] Includes columbium and tantalum in ferrotantalum-columbium, if any.

[2] Withheld to avoid disclosing company proprietary data; included with "Steel: Unspecified."

[3] Ferrocolumbium only.

PRICES

The price of columbium as it is used in largest quantity—regular grade ferrocolumbium by the steel industry—and that of its corresponding raw material—pyrochlore—both remained relatively steady throughout 1978-79. Spot price for the regular grade of ferrocolumbium containing 63% to 68% columbium per pound of contained columbium, f.o.b. shipping point, stayed at $5.12 during 1978 and the first half of 1979, after which the price was advanced to $5.42-$5.73 for the rest of the year, an average increase of 9%. Quoted price for Brazilian pyrochlore, based on approximate official Brazilian export price, f.o.b. shipping point, 50% to 55% Cb_2O_5, was unchanged at $2.55 per pound of contained pentoxide during the 2-year period.

By contrast, prices increased significantly for columbite, tantalite, and the family of products made from these raw materials. Tantalum prices escalated more rapidly and by a higher percentage than did columbium prices, and by even more in 1979 than in 1978. The spot price for tantalite, 60% basis c.i.f. U.S. ports per pound of contained Ta_2O_5, led the rise, going from $22.75-$26.50 at the beginning of 1978 to $90-$95 at the end of 1979. The approximate spot tantalite price increase was 60% in 1978 and 130% in 1979. The price of Canadian (Tanco) tantalite rose nearly as rapidly, advancing from $24 to $75 during the same time interval, also per pound of contained pentoxide. These rapid changes in raw materials prices markedly affected the published price quotations for the various tantalum mill products, powders, and compounds. The price of these products was in the vicinity of $60 per pound at the start of 1978 and $200 per pound at the end of 1979.

The average spot price for columbite concentrates, per pound of combined columbium and tantalum pentoxides c.i.f. U.S. ports, increased by a relatively modest 10% in 1978 but more than doubled in 1979. The price was $2.85-$3.50 in January 1978 and $10-$12 in December 1979. As a result, the price of high-purity ferrocolumbium rose significantly, from $13.45 to $30.15-$35.75 per pound of contained columbium for the same respective dates.

FOREIGN TRADE

Trade in columbium and tantalum metal, alloys, ores, mineral concentrates, and ferrocolumbium resulted in a net deficit of nearly $15 million in 1978 and more than $16 million in 1979. Trade in columbium materials produced deficits of $27 million and $39 million in 1978 and 1979, respectively; for tantalum materials, there were surpluses of $13 million in 1978 and $22 million in 1979. Increases in the value of trade in tantalum materials were largely because of higher unit values, especially in 1979.

Value of exports of tantalum metal, alloys, powder, and scrap rose by 37% in 1978 and by 101% in 1979. Exports of tantalum ores and concentrates were 64,000 pounds at a value of $424,000 in 1978 and 230,000 pounds at a value of $3,046,000 in 1979; Japan was a principal recipient in both years. In addition, 99,000 pounds of tantalum ores and concentrates were reexported in 1979 at a value of $2,865,000, chiefly to Belgium and Japan.

Value of imports for consumption of columbium and tantalum metal, alloys (including ferrocolumbium), waste, and scrap increased 53% in 1978 and 60% in 1979. In each year, the quantity of ferrocolumbium imported grew by over 2 million pounds.

Imports for consumption of columbium mineral concentrates rose in 1978 but dropped back in 1979 to a level not much greater than that in 1977. Value increased by roughly 40% in both 1978 and 1979, however, because of progressive advances in unit value. Imports in 1978 were estimated to contain 1,799,000 pounds of columbium and 145,000 pounds of tantalum; imports in 1979 were estimated to contain 1,485,000 pounds of columbium and 133,000 pounds of tantalum. For both years, the average grade was approximately 60% Cb_2O_5 and 4% Ta_2O_5. Brazil, Canada, and Nigeria remained the leading import sources, with Brazil and Canada principally supplying pyrochlore and Nigeria supplying columbite.

Imports for consumption of tantalum mineral concentrates were relatively constant. Rising tantalum ore prices caused value to increase 27% in 1978 and 165% in 1979. Imports in 1978 were estimated to contain 451,000 pounds of tantalum and 183,000 pounds of columbium; imports in 1979 were estimated to contain 497,000 pounds of tantalum and 205,000 pounds of columbium. In both years, the average grade was nearly that of a 60% concentrate with a Ta_2O_5-to-Cb_2O_5 ratio of 2:1. Canada was the principal supplier of tantalite.

Net receipts of tin slags, synthetic concentrates, and various other raw materials collectively were the most important source of tantalum feedstocks, according to reports of processors. Thailand and Malaysia were again the main sources of tin slags, those from Thailand having the higher tantalum and columbium contents. Sizable quantities of tin slags were reshipped.

Table 7.—U.S. foreign trade in columbium and tantalum metal and alloys, by class and principal country

(Thousand pounds, gross weight, and thousand dollars)

Class	1978		1979		Principal destinations and sources, 1979
	Quantity	Value	Quantity	Value	
EXPORTS					
Columbium:					
Unwrought, and waste and scrap	([1])	([1])	([1])	([1])	([1])
Wrought	([1])	([1])	([1])	([1])	([1])
Tantalum:					
Powder	211	11,033	296	26,060	Japan 91, $9,120; Federal Republic of Germany 90, $7,287; France 44, $3,806.
Unwrought, and waste and scrap	622	13,757	336	22,270	Federal Republic of Germany 279, $16,865; Japan 28, $2,624; United Kingdom 11, $1,251.
Wrought	64	4,456	90	10,363	Japan 26, $3,201; United Kingdom 19, $1,967; Federal Republic of Germany 14, $1,689.
Total exports	XX	29,246	XX	58,698	Federal Republic of Germany, $25,800; Japan, $14,900; United Kingdom, $6,700.[2]
IMPORTS FOR CONSUMPTION					
Columbium:					
Ferrocolumbium[e]	6,398	17,837	8,485	25,321	All from Brazil.
Unwrought metal, and waste and scrap	([3])	4	1	19	Federal Republic of Germany, ([3]) $13.
Unwrought alloys	--	--	--	--	None.
Wrought	([3])	1	7	123	Federal Republic of Germany 7, $123.
Tantalum:					
Waste and scrap	118	1,278	129	2,292	Mexico 57, $325; France 26, $307; United Kingdom 17, $761; Japan 6, $427.
Unwrought metal	69	2,827	48	4,657	Federal Republic of Germany 43, $4,361.
Unwrought alloys	37	1,394	55	5,016	All from Federal Republic of Germany.
Wrought	1	88	1	138	Austria, ([3]) $72; Netherlands, ([3]) $55.
Total imports for consumption[4]	XX	23,429	XX	37,567	Brazil, $25,300; Federal Republic of Germany, $9,700.[2]

[e] Estimate. XX Not applicable.
[1] Not available; included in basket category as of 1978.
[2] Rounded.
[3] Less than 1/2 unit.
[4] Data may not add to totals shown because of independent rounding.

Table 8.—U.S. imports for consumption of columbium-mineral concentrates, by country

(Thousand pounds and thousand dollars)

Country	1978		1979	
	Gross weight	Value	Gross weight	Value
Belgium-Luxembourg[1]	--	--	33	167
Brazil	1,103	2,417	769	2,436
Canada	1,218	2,755	1,124	2,710
China, mainland	263	477	278	2,111
Germany, Federal Republic of[1]	68	110	131	269
Malaysia	110	388	168	1,463
Mexico	([2])	([2])	--	--
Netherlands[1]	--	--	147	113
Nigeria	1,335	2,726	903	3,782
Thailand	182	758	15	24
United Kingdom[1]	--	--	1	7
Total	4,279	9,631	3,564	[3]13,083

[1] Presumably country of transshipment rather than original source.
[2] Less than 1/2 unit.
[3] Data do not add to total shown because of independent rounding.

Table 9.—U.S. imports for consumption of tantalum-mineral concentrates, by country

(Thousand pounds and thousand dollars)

Country	1978		1979	
	Gross weight	Value	Gross weight	Value
Australia	122	1,278	229	6,627
Belgium-Luxembourg[1]	3	27	--	--
Brazil	174	1,618	179	4,516
Canada	667	5,880	679	10,955
Malaysia	66	80	60	417
Mozambique	9	25	25	1,237
Rwanda	123	600	131	1,499
South Africa, Republic of	--	--	2	35
Spain	59	444	83	2,058
Thailand	37	126	48	1,110
United Kingdom[1]	9	103	1	35
Zaire	160	1,177	75	1,201
Zambia	--	--	20	444
Total	1,429	11,358	1,532	[2]30,135

[1] Presumably country of transshipment rather than original source.
[2] Data do not add to total shown because of independent rounding.

WORLD REVIEW

World production of columbium and tantalum minerals is detailed in table 10. In addition, the tantalum contained in tin slags produced in 1976, 1977, and 1978 was, in thousand pounds, 742, 833, and 790, respectively, on the basis of data from the Tantalum Producers International Study Center (TIC). No data were available for the U.S.S.R. for either minerals or slag. Exclusive of the U.S.S.R., the TIC data were believed to represent over 90% of the recoverable tantalum contained in tin slag. As with the data presented in this chapter, an independent review indicated that the world supply of tantalum came almost equally from ore and from tin slag. The review further indicated that tantalum availability was about 85% dependent on tin mining and smelting.[3]

In addition to the activities specifically detailed in the following sections, exploration for columbium and/or tantalum was reported during 1978-79 as having taken place in Bolivia, China mainland, Ghana, Kenya, Tanzania, other African countries, and Saudi Arabia.

Australia.—Production of tantalite concentrates typically grading 40% Ta_2O_5 by Greenbushes Tin N.L., the chief tantalum producer, was 116 metric tons during the 1978 fiscal year ending June 30 and 89 metric tons during fiscal 1979; 1.2 and 1.3 million cubic meters of ore were processed in fiscal 1978 and 1979, respectively. At this level of operations, proven pegmatite reserves as of October 1978 were equivalent to 3 years of mine life. Greenbushes Tin was moving toward vertical integration of operations at their site in Western Australia by setting up a pilot plant to chemically extract tantalum oxide and columbium oxide from low-grade tantalite concentrates. Also on the same scale, the company was testing electric furnace tin smelting with coproduction of tantalum-rich slags. Adding to Australia's tantalum output were the operations of Goldrim Mining Australia Ltd.; Pilgan Mining Pty., Ltd.; and Endeavour Resources N.L. Tantalum production by these companies was also from mines in Western Australia (in the Pilbara region), and together was reported to have been about 50,000 pounds of contained tantalum in 1979.

Brazil.—The Brazilian Niobium Institute was established in 1979 at Lorena, São Paulo State. Supported by the Government, the Institute was to develop technology that would expand use of columbium from Brazil's extensive deposits.

Companhia Brasileira de Metalurgia e Mineração (CBMM) embarked on a major expansion program calling for a total investment of $44 million at its Araxá complex in Minas Gerais State. Annual capacity for treating pyrochlore ore was to be increased by the second quarter of 1981 to 55 million pounds of Cb_2O_5 by construction of a new mill and flotation plant. The present 32-million-pound-per-year plant would then be placed on standby. Metallurgical facilities for converting increased concentrate output to ferrocolumbium were to be expanded accordingly. In addition, columbium oxide was to be produced beginning in 1980 at a new installation having an initial annual capacity for oxide of 3 million pounds.

Production and exports of ferrocolumbium both successively set new records in 1978 and 1979, with almost all the ferrocolumbium produced being exported. In short tons, production of ferrocolumbium was 11,300 in 1978 and 15,300 in 1979; exports were 11,600 and 14,600, respectively. Over 80% of production was by CBMM and the balance by Mineração Catalão de Goías S.A.

Canada.—Columbium production statistics for the Niobec Inc. mine at St. Honoré, Quebec, as reported by Teck Corp., Ltd., for the 1978 and 1979 fiscal years ending September 30, were respectively as follows: Short tons of ore milled, 616,000 and 627,000; Cb_2O_5 grade, 0.66% and 0.67%; pounds of Cb_2O_5 produced, 5,707,000 and 5,445,000; recovery, 66% and 65%. Ore reserves were placed in 1978 at 7,582,000 tons at an average grade of 0.69% Cb_2O_5 and were increased in 1979 to 10,523,000 tons at an average grade of 0.66% Cb_2O_5. Production was to be expanded 30% by underground development and mill enlargement in 1979-81 at a cost of C$10 million.

Tantalum production statistics for the Bernic Lake, Manitoba, mine of Tantalum Mining Corp. of Canada Ltd. (Tanco) for 1978 and 1979, respectively, were as follows: Tons of ore mined, 172,000 and 181,000; Ta_2O_5 grade, 0.148% and 0.137%; pounds of Ta_2O_5 produced, 340,000 and 344,000; recovery, 65% and 69%. Higher tantalum prices lowered cutoff ore grade, extended mine life to the latter 1980's, and led to expansion of the metallurgical plant. The expansion, which began in late 1979 and was to be completed by mid-1980, was to increase annual throughput capacity from 175,000 tons to 250,000 tons by allowing reprocessing of 75,000 tons per year of tailings. International Chemalloy Corp. ceased to be a part owner of Tanco in 1978. After a series of share transactions, the 1 million outstanding Tanco shares were distributed between KBI (37.5%) and, in Canada, Hudson Bay Mining and Smelting Co., Ltd. (37.5%) and the Manitoba Development Corp. (25%), a Crown agency of the Manitoba Government. The Canadian Metals Division of Hudson Bay Mining and Smelting assumed responsibility for overall operations of Tanco.

Japan.—Mitsui Mining & Smelting Co., Ltd., completed and put into operation in 1979 facilities for treating low-grade tantalite. Processing was to include concentrate pretreatment to raise Ta_2O_5 content prior to its use in tantalum production.

Nigeria.—Production of columbite as a byproduct of tin mining by Amalgamated Tin Mines of Nigeria Ltd. (ATMN), Bisichi-Jantar (Nigeria) Ltd., Gold and Base Metal Mines of Nigeria, Ltd., and Vectis Tin Mines Ltd. dropped off in both 1978 and 1979, by 19% and 11%, respectively, compared with that of the previous year. The combined totals for the group were 643 metric tons in 1978 and 571 metric tons in 1979. Bisichi-Jantar and ATMN accounted for most of the output. Most of the decline in 1979 was at ATMN, where equipment and soil stability problems were encountered. Mining for columbium was suspended at Vectis' Odegi operation in May 1978 because of low columbite profitability, but was resumed in September 1979 under a management agreement with ATMN. The parent companies of ATMN, Bisichi-Jantar, and Gold and Base Metal Mines all were engaged in a required "Nigerianization" of ownership, according to which Nigerian interests were to acquire at least 60% of the operating mining companies. Amalgamated Tin Mines of Nigeria (Holdings) Ltd. achieved this limitation to its ownership of ATMN principally through sale of ATMN shares to the State-owned Nigerian Mining Corp.

Southeast Asia.—Future prospects for tantalum production in association with tin mining were being encouraged by exploration for tin off the coasts of Malaysia, Thailand, and Indonesia. Supply of tantalum was being augmented by increased efforts at its recovery in such low-grade forms as struverite from amang mining wastes in Malaysia and Thailand. The high value of tantalum led to a number of instances of unauthorized digging up of old tin slag deposits on Phuket Island. Factors working against growth of the tin mining industry were rising costs and taxes and, in Malaysia, regulation at the State level. Smuggling of Southeast Asian tin ore, reportedly to Singapore, was a continuing concern, and may have been on such a scale as to unfavorably affect recovery of tantalum from the area by as much as 10%.

Established patterns of tin smelting and recovery of tantalum-bearing slags therefrom were facing change. In Thailand, two new tin smelters were projected, both for

Table 10.—Columbium and tantalum: World production of mineral concentrates by country[1]

(Thousand pounds)

Country[2]	Gross weight[3]				Columbium content[4]				Tantalum content[4]			
	1976	1977	1978[p]	1979[e]	1976	1977	1978[p]	1979[e]	1976	1977	1978[p]	1979[e]
Argentina:												
Columbite	(5)	1	(5)	(5)	(5 6)	[6]1	(5)	(5)	(5 6)	(5 6)	(5)	(5)
Tantalite	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)
Australia: Columbite-tantalite[7]	273	348	275	360	69	62	58	70	87	118	91	120
Brazil:												
Columbite-tantalite	436	303	448	600	98	56	83	110	128	95	141	200
Pyrochlore	41,894	34,421	39,412	43,300	[e]17,571	[e]14,436	[e]16,529	18,160	--	--	--	--
Burundi: Columbite-tantalite	9	[e]10	--	--	2	2	--	--	2	2	--	--
Canada:												
Pyrochlore	[r] [e]5,505	[r] [e]9,220	[e]9,087	[e]8,556	[r] [e]2,309	[e]3,866	[e]3,811	[e]3,708	--	--	--	--
Tantalite	[e]520	595	624	640	15	17	17	18	[e]231	[e]265	[e]278	285
Malaysia: Columbite-tantalite	101	99	51	120	43	39	13	30	12	15	4	10
Mozambique:												
Columbite[6]	4	5	5	5	1	1	1	1	2	2	2	2
Microlite	123	88	88	70	5	4	4	3	68	48	48	40
Tantalite[6]	62	80	80	70	8	13	13	10	27	33	30	25
Nigeria:												
Columbite	[r]1,561	1,898	1,468	1,150	[r]687	773	646	500	[r]89	175	88	70
Tantalite	2	3	2	1	1	(5)	(5)	(5)	1	2	1	1
Portugal: Tantalite	11	7	18	11	3	2	4	3	3	2	4	3
Rhodesia, Southern: Columbite-tantalite[6]	90	90	90	100	10	10	10	11	[r]24	24	25	28
Rwanda: Columbite-tantalite	100	142	107	110	29	44	33	35	24	30	19	20
Thailand:												
Columbite	(8)	73	141	73	(8)	16	32	16	(8)	13	23	12
Tantalite	15	90	--	90	[r]3	18	--	18	4	24	--	23
Uganda: Columbite-tantalite[6]	5	5	5	5	1	1	1	1	1	1	1	1
Zaire: Columbite-tantalite	174	183	41	70	48	41	11	20	46	56	9	15
Total	[r]50,885	47,661	51,942	56,331	[r]20,908	19,402	21,263	22,714	[r]749	905	764	855

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[e] Estimate. [p] Preliminary. [r] Revised.

[1] Excludes columbium and tantalum-bearing tin ores and slags.

[2] In addition to the countries listed, China mainland, Spain, the Territory of South-West Africa, the U.S.S.R., and Zambia also produce or are believed to produce columbium and tantalum mineral concentrates, but available information is inadequate to make reliable estimates of output levels.

[3] Data on gross weight generally has been presented as reported in official sources of the respective countries, divided into concentrates of columbite, tantalite, pyrochlore, and microlite where information is available to do so, and reported in groups such as columbite and tantalite where it is not.

[4] Unless otherwise specified, metal content is based on U.S. Bureau of Mines estimates.

[5] Less than 1/2 unit.

[6] Reported in official country sources.

[7] Exports.

[8] Revised to zero.

relatively small installations near Bangkok to operate on native ore feed. Thai Pioneer Enterprise Ltd. planned for an electric furnace unit that was to start production late in 1980 at an initial annual rate of about 4,000 metric tons of tin. Annual production capacity of a smelter proposed by Thai Present Co. was 6,000 metric tons of tin. In Malaysia, consideration to move the smelter of Datuk Keramat Smelting Sdn. Bhd. at Penang to the mainland was revived, and the Malaysia Mining Corp. was debating whether to build its own smelter rather than to continue with present toll-processing arrangements.

TECHNOLOGY

Developments in technology of the production and application of columbium and tantalum were the subject of a number of reviews dealing with gravity concentration of ores,[4] use of columbium as a microalloying element in HSLA steels,[5] status and metallurgy of HSLA steels,[6] superconducting materials,[7] and tantalum carbide worldwide.[8]

Improvements in Canadian practices for mining and beneficiation of both columbium and tantalum ore were reported. At the Niobec columbium mine, St. Honoré, Quebec, developments in drop raise drilling and blasting techniques, evolving from practices used at the similar Oka deposit of St. Lawrence Columbium and Metals Corp., have lowered overall mining costs.[9] At the Niobec concentrator, 15.5 tons of pyrochlore concentrate grading 62.4% Cb_2O_5 were obtained from 1,960 tons of mill feed from the St. Honoré carbonatite complex at 70% recovery in a typical day. Operational details were described.[10] Tanco's equipment and procedures at Bernic Lake, Manitoba, for production of tantalum concentrates were discussed, including those for assaying and the spot-lot production of cesium and rubidium ores and such specialty products as spodumene, feldspars, and high-purity quartz.[11] Decreases in tantalite grade and liberation size from those pertaining over 10 years ago, when Tanco began operations on its pegmatite ore body, have necessitated changes in the gravity circuit of the mill. Recent installation of a spiral circuit, and concurrent improvements in the slime circuit and in screening, have raised recovery from 60% to over 70%, even though average head grade, at 0.14% Ta_2O_5, has fallen to less than half its original value. Typical daily production from the concentrator was reported as 1.7 tons of concentrate averaging 50.5% Ta_2O_5 from 725 tons of feed.[12]

A process applicable to the manufacture of high-purity ferrocolumbium was developed by modifying the conventional sequence of operations in which columbium oxide is produced as an intermediate. Beginning with a columbium fluoride solution as usual, a columbium oxyfluoride intermediate was prepared by evaporating the solution to dryness. It was found that the oxyfluoride could next be used as a feed material for aluminothermic production of ferrocolumbium.[13]

Columbium was used along with vanadium as a microalloying element in a newly developed HSLA as-hot-rolled bar steel. This steel, carbon-manganese steel with a ferrite-pearlite microstructure, was designed to have a minimum yield strength of 80,000 psi along with good weldability and bendability, as an alternative to quenched and tempered steels of comparable strength. The new steel was seen to have potential for use in various transportation applications where advantage could be taken of its good strength-to-weight characteristics.[14] Other new areas of application for columbium in steel that were under investigation included cast HSLA steel microalloyed with columbium and vanadium[15] and columbium as a partial replacement for vanadium, tungsten, or molybdenum in high-speed tool steel.[16]

Columbium-titanium served as superconductor for magnet coils in two development programs. The Westinghouse Electric Corp. was using this alloy in constructing a 300 megavolt-ampere (MVA) power generator in a major step taken toward the eventual achievement of a commercial generator with a rating as large as 1,200 MVA.[17] On a smaller scale, testing of a pilot superconducting unit for wet magnetic separation of minerals continued at the Imperial College in London.[18]

With the objective of enlarging the raw materials resource base for columbium superconductors, the Teledyne Wah Chang Albany Div. of Teledyne Inc. investigated the effect of a tantalum addition of as much as 2% on the superconducting properties of columbium-titanium. Indications were that these levels of tantalum, such as might be introduced if pyrochlore were used as columbium raw material, impaired neither superconductivity nor workability.[19]

Research on columbium-germanium was active because this compound exhibits superconductivity to higher temperatures and sustains greater magnetic fields than either columbium-titanium alloy or columbium-tin compound, the most widely used superconductors. A possible way of overcoming problems in fabricating brittle compounds like Cb_3Ge was developed in the Research Division of the International Business Machines Corp. The glass-forming tendencies of germanium enabled Cb_3Ge to be deposited as an amorphous film, using a thin tape of tantalum or copper as substrate. The composite tape could then be readily shaped into magnet coils. As deposited the film was a normal conductor, but annealing transformed it into a crystalline superconductor.[20] In other work on Cb_3Ge, procedures for producing long lengths of Cb_3Ge-clad tapes by means of chemical vapor deposition were developed at the Los Alamos Scientific Laboratory. These tapes were made in lengths of 20 meters during one phase of a program on alternating current superconducting power transmission lines.[21]

Advances in tantalum capacitor technology included development of a chip type of tantalum capacitor having electrical and physical properties comparable to those of conventional pellet-wire capacitors. Design and fabrication of the chip capacitor were chosen so as to minimize handling of individual capacitors.[22] Performance and reliability of wet-slug tantalum capacitors were improved by changing the case material from the usual silver to tantalum in order to minimize in-service problems due to silver whiskering and electrolyte seepage. All-tantalum wet-slug capacitors were expected to be selected for critical applications, particularly in aerospace and military hardware.[23]

Replacement in cemented carbides of tantalum carbide by hafnium-columbium carbide was investigated in response to price and supply problems of tantalum. A hafnium-columbium carbide solid solution containing roughly equal molar amounts of hafnium and columbium was substituted for tantalum carbide on the basis of equivalent alloying. Tests on samples of roughing and light-finishing cutting tool grades made with this substitution indicated that properties comparable to those of tantalum-containing compositions could be obtained.[24]

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[1] Physical scientist, Section of Ferrous Metals.

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Copper

By James H. Jolly[1]

Although world mine production of copper fell in 1978, demand increased significantly, reducing the large excess of copper stocks built up in the preceding 3 years. In 1979, world copper production improved slightly, demand continued to increase and world stocks were further reduced. A number of new mines came onstream in 1979 and excess capacity at some operations began to be utilized. The United States continued to lead the world in mine output with about 19% of the total in 1979, followed by Chile, the U.S.S.R., Canada, Zambia, Peru, Zaire, Poland, the Philippines, Australia, and the Republic of South Africa. Labor strikes adversely affected Canadian copper production from late 1978 to mid-1979, and production in central Africa was curtailed during both years owing to political, economic, and transportation problems.

Table 1.—Salient copper statistics

	1975	1976	1977	1978	1979
United States:					
Ore produced ______ thousand metric tons__	238,592	257,401	235,844	239,247	264,790
Average yield of copper __________percent__	0.47	0.51	0.52	0.51	0.49
Primary (new) copper produced—					
From domestic ores, as reported by—					
Mines ____________metric tons__	1,282,184	1,456,561	1,364,374	1,357,586	1,443,556
Value ______________thousands__	$1,814,763	$2,234,975	$2,009,297	$1,990,323	$2,960,676
Smelters ____________metric tons__	1,246,766	1,325,629	1,265,008	1,269,961	1,313,224
Percent of world total ___________	17	17	16	16	16
Refineries__________metric tons__	1,166,811	1,290,673	1,280,035	1,327,373	1,411,518
From foreign ores, matte, etc., as reported by refineries ________________do____	142,600	105,764	77,281	121,684	103,858
Total new refined, domestic and foreign __________do____	1,309,411	1,396,437	1,357,316	1,449,057	1,515,376
Secondary copper recovered from old scrap only ____________do____	334,908	380,225	409,928	501,650	604,301
Exports: Refined______________do____	156,422	101,502	46,745	91,923	73,677
Imports, general:					
Unmanufactured ____________do____	294,042	485,084	468,769	546,389	328,823
Refined _________________do____	133,179	346,113	354,506	414,697	215,161
Stocks Dec. 31: Producers:					
Refined________________do____	187,000	172,000	212,000	153,000	64,000
Blister and materials in solution ______________do____	283,000	291,000	314,000	263,000	275,000
Total ________________do____	470,000	463,000	526,000	416,000	339,000
Consumption:					
Refined copper ____________do____	1,392,083	1,807,008	1,982,162	2,189,301	2,158,442
Apparent consumption, primary copper____________do____	1,191,000	1,656,000	1,625,000	1,831,000	1,746,000
Apparent consumption, primary and old copper (old scrap only) ____________do____	1,526,000	2,036,000	2,035,000	2,333,000	2,250,000
Price: Weighted average, cents per pound______________________	64.2	69.6	66.8	66.5	93.3
World:					
Production:					
Mine ______________metric tons__	7,009,487	7,451,400	7,661,200	7,557,300	7,606,800
Smelter______________do____	7,319,799	7,769,500	8,029,400	7,924,100	8,035,600
Price: London, average cents per pound______________________	56.08	63.92	59.44	61.88	90.07

Copper prices, low throughout 1978, increased rapidly in 1979 in response to strong demand, decreasing stock levels, and reaction to rapidly rising precious metal prices and to increased speculation on the copper futures market. The copper price per pound averaged 93 cents in 1979 compared with 66 cents in 1978. In the United States, a major change in copper pricing occurred in 1978, when several major producers dropped the traditional producer price system and adopted a pricing mechanism based on commodity exchange prices.

Legislation and Government Programs.—As a result of this change, a single world price for copper has tended to be established. The stockpile goal of 1.18 million tons[3] of copper, established in 1976, remained in effect; however, the Federal Emergency Management Agency (FEMA), formerly the Federal Preparedness Agency, was reassessing the goal. At the end of 1979, the copper stocks in the stockpile totaled only 20,228 tons. No program was announced for purchases against the goal.

New duties and a tariff reduction schedule for imports of copper materials negotiated under the General Agreement on Tariffs and Trade during the Tokyo Round were established in July 1979. Duty reductions were to be phased in over an 8-year period beginning January 1, 1980.

On August 23, 1978 the International Trade Commission (ITC), in response to a petition by domestic copper producers, determined that the domestic producers were being injured by increased imports of refined copper and recommended to the President that annual refined copper import quotas be imposed. In October 1978, the President rejected the ITC recommendations as not being in the national interest. The decision was based on a number of considerations including the anticipated negative effects on negotiations toward further liberalization of world trade, the inflationary aspects of import restrictions, and the fact that the copper market was recovering from its depressed condition.

DOMESTIC PRODUCTION

Mine Production.—Domestic mine production of recoverable copper in 1978 remained at the 1977 level, but increased significantly in 1979 in response to improved prices and market conditions. Principal copper-producing States in 1979 were Arizona, Utah, New Mexico, Montana, and Michigan. Mine production in Nevada, generally one of the leading producing States, fell to low levels in 1978 and 1979 owing to mine closures.

The Anaconda Copper Co., a subsidiary of the Atlantic Richfield Co. (ARCO), produced copper principally from the Berkeley open pit at Butte, Mont. in 1978 and 1979. Anaconda's Yerington copper mine at Weed Heights, Nev. was closed on June 30, 1978, because of unprofitable operation. The company's new $220 million Carr Fork underground mine near Tooele, Utah, began production in October 1979 and was expected to reach design production capacity (50,000 tons of copper in concentrates annually) in late 1980. Carr Fork reserves were about 55 million tons of ore averaging 1.84% copper with significant quantities of molybdenum, gold, and silver.

Anamax Mining Co., a joint venture of Anaconda and Amax Inc., produced 96,893 tons of copper in concentrate in 1979 and 59,339 tons in 1978 at its Twin Buttes mine in Arizona. The 74% production increase in 1979 was the result of operating the mill at design capacity (36,000 tons per day), improved copper recovery, and the first milling of ore from the nearby Eisenhower mine of the Eisenhower Mining Co., a partnership of Anamax and ASARCO Incorporated. Most of the concentrates produced were exported to Japan. The Twin Buttes oxide copper plant operated at capacity in 1978 and 1979, producing 32,484 tons of electrowon cathodes in 1978 and 31,908 tons in 1979. Twin Buttes' ore reserves in 1979 were estimated to be 284 million tons of sulfide ore grading 0.66% copper and 40 million tons of oxide ore grading 0.99% copper. In October 1979 the Federal Trade Commission approved a consent order for Anaconda to divest itself of several copper properties in order to settle litigation resulting from ARCO's 1977 acquisition of Anaconda. Under the agreement Anaconda must divest the major portion of its interest in Anamax within 5 years.

Eisenhower, which started development of the Palo Verde deposit (Eisenhower mine) in 1976, began ore shipments in January 1979. Ore from the mine is processed at ASARCO's Mission Unit concentrator and at Anamax's Twin Buttes concentrator. Under terms of the agreement, ASARCO, the operating company, was to supply Anamax with 4.5 million tons of ore per year for 21 years and half that amount annually for the next 8 years. Ore reserves were estimated to be 142 million tons grading 0.6% copper.

ASARCO operated four copper mines, the Mission, Sacaton, Silver Bell, and San Xavier units, in Arizona in 1978 and 1979. The four mines produced 87,640 tons of copper in 1978 and 80,740 tons in 1979. The 1979 production decrease was mainly due to the closing down of the leach plant at San Xavier in November 1978, when the supply of oxide ore it treats was exhausted. In 1978, ASARCO decided to proceed with development of the Troy mine in western Montana at a cost of $83 million. The mine, which is scheduled to start up in mid-1981, was expected to have an annual capacity of 4.2 million troy ounces of silver and 18,100 tons of copper contained in concentrates.

Cities Service Co., operators of copper mines in Arizona and Tennessee, resumed development in late 1979 of its underground Miami East mine in Arizona. Plans called for production of 9,000 tons of copper by 1982. Cities Service also was planning construction of a second solvent-extraction electrowinning facility at its Pinto Valley operations to recover an additional 4,500 tons of copper per year. These two projects, expected to cost a total of $40 million, would boost the copper production capacity of the company's Miami operations to 91,000 tons per year. Copper production from Miami operations was 73,500 tons in 1978 and 70,300 tons in 1979.

Cyprus Mines Corp. a subsidiary of Standard Oil Co. (Indiana), reopened its Pima mine near Tucson, Ariz. in mid-1979 at a daily ore-milling rate of 16,800 tons, compared with 50,000 tons per day prior to cessation of operations in September 1977 due to low copper prices. Pima's ore reserves were 134 million tons averaging 0.497% copper at the end of 1978. Copper production at the company's Cyprus Bagdad operation, also in Arizona, increased almost fourfold in 1978 following completion of a $240 million mine and mill expansion in late 1977. Cyprus Bagdad milled 12.3 million tons of 0.52% copper sulfide ore in 1978 producing 52,730 tons of copper in concentrates. Total 1978 copper production, including copper electrowon from oxide ore, was 59,470 tons compared with 20,990 tons in 1977. The sulfide concentrates from the 40,000-ton-per-day Bagdad mill was processed in 1978 and 1979 at the Phelps Dodge Corp. Hidalgo smelter in New Mexico. Bagdad's ore reserves at yearend 1979 were about 238 million tons of sulfide ore grading about 0.49% copper and 18 million tons of oxide ore grading 0.37% copper.

Duval Corp., a subsidiary of Pennzoil Co., operated the Sierrita, Esperanza, and Mineral Park copper-molybdenum open pit mines in Arizona and the Copper Canyon open pit copper-gold mine in Nevada in 1978 and 1979. The Esperanza property was closed during 1978 and early 1979, although some copper was produced from dump leaching operations. In April 1979 Duval resumed ore production at a full production rate of 16,000 tons per day. Duval's Copper Canyon operations were affected by a long strike in late 1978, delaying until mid-1979 the opening of a new solvent extraction electrowinning plant capable of producing 18 tons per day cathode copper.

Inspiration Consolidated Copper Co., a subsidiary of Hudson Bay Mining and Smelting Co., Ltd., produced copper from a number of open pit and leach operations near Inspiration, Ariz. in 1978 and 1979. The concentrator at Inspiration treated 16,000 tons per operating day in 1979 producing 19,840 tons of copper in concentrates; in 1978 the mill treated 16,960 tons of ore per day but operated for less days, yielding 17,990 tons of copper in concentrates. The new $14 million solvent-extraction plant came onstream in October 1979 and was producing 20 tons of high quality cathodes per day by the end of the year. In the second half of 1980, capacity production of 45 tons per day was expected. The Ox-Hide open pit was not mined in 1978 or 1979; but copper recovery by dump leaching totaled 1,881 tons in 1978 and 553 tons in 1979. Operations at Inspiration's Christmas open pit mine, 35 miles southeast of Inspiration, were resumed in mid-1979. Copper recovery from Christmas ores totaled 5,596 tons for 1979.

Kennecott Copper Corp. was the principal U.S. copper producer in 1979 (351,810 tons). Kennecott operated mines in Arizona, New Mexico, Nevada, and Utah during the 1978-79 period; however, operations at the company's Nevada Mines Div. were suspended on May 1, 1978, due to unfavorable conditions in the copper market. In mid-1979 Kennecott announced plans for a $280 million expansion program at its Chino Mines Div. (New Mexico) to increase production by 60% and drastically lower per-unit production costs. The project was to include building a 33,570-ton-per-day concentrator to replace the present 20,870-ton-per-day mill, eliminating rail haulage of ores and concentrates, and expanding production of ore from the Santa Rita open pit mine. The Ray Mines Div. (Arizona) was building a solvent-extraction plant to improve the electrowinning cycle at its copper silicate leach plant.

Magma Copper Co. operated two underground copper mines in Arizona producing 145,000 tons of refined copper in 1979 and 146,000 tons in 1978. Daily production at the San Manuel mine averaged 55,300 tons of 0.63% copper ore in 1979, compared with 49,660 tons of 0.64% copper ore in 1978. At the Superior mine daily production averaged 2,480 tons of 4.41% copper ore in 1979 compared with 2,672 tons of 4.36% copper ore in 1978. Magma continued development of the Kalamazoo ore body, which is deeper than and adjacent to the San Manuel deposit. Initial production from the Kalamazoo ore body was planned for 1983.

Hecla Mining Co. and El Paso Natural Gas Co., joint developers of the Lakeshore underground copper mine (Arizona) which closed in September 1977, wrote off their investment in the mine and terminated their lease with the Papago Indian tribe in October 1978. In April 1979 the Lakeshore ore body was leased to Noranda Exploration Inc. Noranda planned to spend about $25 million to bring the oxide ore portion of the mine onstream at a 5,500-ton-per-day rate by July 1980. Mining of the sulfide ore was to be delayed until 1983 or later. Oxide ore reserves were estimated to be 20 million tons grading 1.19% copper.

In 1978 and 1979 Phelps Dodge Corp. operated four open pit copper mines - Ajo, Metcalf, and Morenci in Arizona and Tyrone in New Mexico. Copper production was 289,400 tons in 1978 and 311,080 tons in 1979, the highest in the company's history. The high production rate in 1979 reflected a threefold increase in the recovery of precipitates from dump leaching programs at Morenci and increased operating schedules at its mines. In 1979 copper output at Morenci, Tyrone, Metcalf, and Ajo was 133,177 tons; 91,264 tons; 44,000 tons and 39,010 tons respectively. Leaching at the closed Bisbee (Arizona) mine contributed 3,357 tons of precipitate copper and miscellaneous sources, 272 tons. Development work at Phelps Dodge's Safford deep copper ore body in Arizona continued; however, no decision was made as to when the deposit will be brought into production.

Ranchers Exploration and Development Corp. production fell substantially to only 4,513 tons in fiscal 1979 (to June 30) compared with 6,711 tons in fiscal 1978 and 8,127 tons in fiscal 1977. Most of the company's fiscal 1979 output was recovered at the Bluebird mine near Miami, Ariz. by a leach-solvent extraction-electrowinning process. About 196 tons of cement copper was produced at the Big Mike mine in Neveda; however, operations at this mine were terminated in January 1979 because reserves had been exhausted. Ranchers resumed development at its Old Reliable mine in Arizona in 1979 and planned to begin in 1980, production of cement copper, the first to be produced since the mine closed in 1975.

Smelter Production.—Copper companies continued to make expensive modifications and additions to their smelters in order to comply with required environmental standards—particularily those involving sulfur dioxide and particulate emissions. Several smelters were expected to be closed in the mid-1980's because the capital cost to comply with environmental regulations was not economically justified. In 1978 and 1979 production at a number of smelters was curtailed because of environmental constraints, principally those involving sulfur dioxide emissions.

Kennecott's new $280 million Garfield smelter in Utah commenced operations on May 30, 1978. The new smelter which utilizes a continuous smelting process developed by Noranda Mines, Ltd., was designed and installed primarily for pollution control purposes. Plans to replace the Hurley smelter in New Mexico were delayed. The Hurley smelter, which captures about 60% of sulfur in the concentrate it treats, will be required to capture about 89% by 1982. Costs to meet this requirement were estimated to be about $100 million.

Refined Production.—In 1978 and 1979 production of refined copper from primary and secondary materials was substantially higher than the depressed 1977 level. In 1979 scrap sources accounted for 28% of refined production.

Copper Sulfate.—Copper sulfate was produced from electrolytic tankhouse solutions, blister copper and secondary metal by companies with plants located as follows:

Company	Plant location
The Anaconda Company	Great Falls, Mont.
Chevron Chemical Co.	Richmond, Calif.
Cities Service Co.	Copperhill, Tenn.
CP Chemicals Inc	Sewaren, N.J.
Madison Industries Inc	Old Bridge, N.J.
Phelps Dodge Refining Corp.	Laurel Hill, N.Y. and El Paso, Tex.
Van Waters & Rogers Inc	Wallace, Idaho.

Copper sulfate production increased significantly in 1978 and 1979 from the low production level of 1977. Of the total shipments in 1978 and 1979 about 62% was for agricultural uses, 35% for industrial uses, and 3% for other uses.

Byproduct Sulfuric Acid.—Sulfuric acid was produced largely from the sulfur contained in smelter offgases. Output in 1979 increased for the 12th consecutive year to a record 3.57 million tons on a 100% acid basis.

Secondary Copper and Brass

Domestic recovery of copper in all forms from all classes of purchased scrap reached a record high in 1979, and was 24% higher than in 1978. About two-thirds was recovered from alloys and one-third from unalloyed copper. Recovery from copper base scrap advanced from 1.2 million tons in 1978 to 1.5 million tons in 1979. In 1979 secondary smelters accounted for 39% of the recovered copper, brass mills for 36%, primary producers for 20%, and chemical plants, foundries, and manufactures for 5%.

Consumption of purchased copper-base scrap in 1979 was a record 2.1 million tons, 28% higher than in 1978 and 45% higher than in 1977. New scrap accounted for 60% and old scrap for 40% in 1979. Of the major categories of copper and copper-alloy products derived from scrap in 1979, the output of brass mill products, unalloyed copper, and brass and bronze ingots accounted for 46%, 34%, and 16% respectively, of the total.

CONSUMPTION

Consumption of refined copper has increased every year since the drastic slump in 1975. In 1979 wire mills accounted for 70% of refined copper consumption; brass mills for 28%; and all other categories, for 2%.

STOCKS

Compared with U.S.-held stocks of refined copper at yearend 1977, stocks fell by 21% in 1978 and by 57% in 1979. Stock declines at the primary producers, wire rod mills, and the New York Merchantile Exchange (COMEX) were particularly substantial in 1979. COMEX stocks decreased from 163,000 tons in 1978 to 90,000 tons in 1979.

PRICES

Average monthly prices of domestic delivered copper increased from about 63 cents per pound in January 1978 to 72 cents in December 1978. In the first few months of 1979, prices rose rapidly months into the 90-cents-per-pound range as a result of strong demand, declining stocks, and reaction to the precious metals and futures markets. Toward the end of 1979, prices exceeded 100 cents per pound spurred on mainly by rapid increases in precious metals and copper futures prices.

In May 1978, a major change in U.S. copper pricing took place. Kennecott, followed by Anaconda in August, dropped the producer price tradition and adopted pricing mechanisms based on COMEX plus a 2.5 cents premium. Since the change, U.S. producer prices have been fluctuating more or less in response to price changes on the London Metal Exchange (LME) and COMEX, such that a single world price for copper has tended to be established.

FOREIGN TRADE

Refined copper imports in 1977 and 1978 reached such proportions that ITC recommended that import quotas be set to prevent further injury to the domestic industry. The ITC recommendations were subsequently rejected by the President (see Legislation and Government Programs). In 1979 refined copper imports were about half the 1978 total, owing mainly to increased domestic production, improved competitive pricing of domestic copper, and strong world demand. Chile, Canada, Peru, and Zambia were the principal import sources of copper in 1978 and 1979.

WORLD REVIEW

World mine production of copper in 1978 and 1979 was less than in 1977 despite improved market demand and rising prices beginning in late 1978. The United States continued to lead the world in mine production with about 19% of the total, followed by Chile 14%, the U.S.S.R. 12%, Canada 9%, Zambia 8%, Peru 5%, Zaire 5%, Poland 4%, the Philippines 4%, Australia 3%, and the Republic of South Africa 2%, and Paupa New Guinea 2%. Market economy countries produced about 81% of total production in 1979.

According to the World Bureau of Metal Statistics (WBMS), world refined copper consumption rose to 9.50 million tons in 1978 and to 9.86 million tons in 1979, the highest recorded. Consumption in 1977 was estimated to be 9.05 million tons. World stocks of refined copper, which increased substantially in the period 1975-77, fell rapidly in 1978 and 1979 to meet increased world demand. According to the WBMS, market economy country stocks fell from 1.96 million tons in 1977 to 1.53 million tons in 1978 and to 1.08 million tons in 1979. Yearend 1979 stocks were equivalent to about 1.7 months of market economy country consumption. Reductions in LME stocks accounted for almost 60% of the total stock decline between 1977 and 1979; decreases in U.S. producer stocks accounted for 21%.

The major copper producing and consuming countries held five meetings in 1978 and 1979 under the auspices of the United Nation's Conference on Trade Development (UNCTAD) to examine the causes of copper market instability and to consider possible ways to correct the problem. No consensus was reached, but further meetings were scheduled in 1980. Among the items slated for further consideration were formation of a producer-consumer forum, buffer stocks, and supply management controls.

Argentina.—Minera Aguilar, a subsidiary of St. Joe Minerals Corp., announced plans to develop the El Pachon porphyry copper deposit. The project, which was expected to produce 100,000 tons of electrolytic copper per year, was estimated to cost $800 to $1,000 million. Production was expected to start in 1984 at a mining rate of 80,000 tons of ore per day. Reserves were estimated to be 790 million tons averaging 0.59% copper with molybdenum, silver, and gold.

Australia.—Although the Australian copper industry increased output in late 1978, production was slightly less than in 1977. Production in 1979 was up appreciably, owing mainly to increased production by Mount Isa Mines Ltd. (MIM) and the first full year's production at Woodlawn Mine Ltd.'s new open pit zinc-lead-copper mine in New South Wales. Because the copper market improved beginning in late 1978, a number of new copper properties were scheduled for development, and several closed mines were to be placed in production. The principal new properties targeted for development were the Olympic Dam deposit of Western Mining Corp. and BP (Australia) Ltd. in South Australia and the Teutonic Bore deposit of Selection Trust Ltd. and MIM in Western Australia. The Dianne mine, operated by White Industries Ltd., began shipments of high grade ore (reserves of 88,000 tons grading 23.6% copper) in late 1979. Peko Wallsend Ltd. was increasing production at its Warrego mine and planned to bring the Gecko mine onstream by mid-1980 to be able to meet the concentrate requirements of its Tennant Creek smelter, to be reactivated and modernized by September 1980. The annual capacity of the smelter was to be 25,000 tons.

Brazil.—Caraiba Metals S. A. Industria e Comercio continued development of the $733 million Caraiba copper project in Bahia. The Caraiba open pit mine, the largest of three mines included in the project, came onstream in September 1979 and was expected to initially produce 40,000 tons of copper in concentrate annually. Together with the Camaqua and Petra Verde mines, these operations were expected to furnish 80,000 tons of copper in concentrate to the new 150,000-ton-per-year copper smelter being constructed at Salvador. Plans called for the smelter to be operational in 1982.

Canada.—Copper production was significantly lower in 1978 and 1979 due mainly to strikes and production cutbacks at mines co-producing nickel and zinc. An 8 1/2 month strike that began in September 1978 at the Sudbury copper-nickel operation of Inco Ltd. was the single most important event affecting Canadian copper production in the 2-year period. Long strikes at the Murdochville, Quebec, operations of Gaspé Copper Mines Ltd. and at Gibraltar Mines Ltd.'s mine in British Columbia also contributed to reduced production. In 1978 British Columbia was the leading copper producing Province with 42% of the total, followed by Ontario, 30%; Quebec, 13%; Manitoba, 9%; and the remaining Provinces, 6%. In 1979 the respective provincial production percentages were 45%, 29%, 13%, 9%, and 4%.

Because of higher earnings and the improved copper outlook in 1979, a number of companies announced plans to expand copper capacities or open new mines. In British Columbia, Craigmont Mines Ltd. decided to extend the life of its Merritt mine until late 1980. The mine had been scheduled for closure in 1979 because of exhaustion of ore reserves. In the Highland Valley area, Teck Corp. and Highmont Mining Corp. were developing a 22,000-ton-per-day open pit mine and mill on the Highmont property adjacent to the Lornex mine. The Highmont mine, which was expected to cost $150 million to develop, was scheduled for production of 23,000 tons of copper annually beginning in 1982. Lornex Mining Corp. also planned to expand mining and milling rates at the Lornex open pit by 68% to about 70,000 tons per day by July 1981 at a cost of $160 million.

Other copper projects in British Columbia included the development of the Sam Goosley silver-copper mine by Placer Development Ltd.; the reopening of the Granduc mine, closed in June 1978, by Esso Minerals Canada Ltd. who bought the mine in 1979; Similkameen Mining Co. Ltd's development of an open pit mine on Copper Mountain across the Similkameen River from its Ingerbelle mine; and the possible development of the Lake Zone deposit by Valley Copper Mines Ltd., a Cominco Ltd. subsidiary.

In Ontario, Texasgulf Inc. continued to expand its Kidd Creek mine and concentrator to increase copper output by 50% in 1981. The expansion of the concentrator was completed in May 1978 with the addition of the fourth circuit that can process 1.2 million tons of ore per year. Construction of a $250 million copper smelter and refining complex at Kidd Creek continued and was about 60% complete. Completion was expected in 1981. Expansion of the No. 2 mine was scheduled for completion in 1981 at which time the Kidd Creek operation will be capable of processing at about 5 million tons of ore per year.

Teck Corp.'s $85 million Afton mine and smelter near Kamloops, British Columbia officially opened in April 1978. The company exported both blister and concentrate in 1978 and 1979. In July, Madeleine Mines Ltd. reopened its mine in Quebec, which had been closed since November 1976 because of low copper prices. Hudson Bay Mining and Smelting Co., Ltd. completed its new 3,800-ton-per-day concentrator in the Flin Flon-Snow Lake area in northern Manitoba and officially began production in June 1979. The concentrator was expected to produce annually about 160,000 tons of copper concentrate in processing ore from five mining operations.

Chile.—Chilean copper production turned upward in 1979 following a decline in 1978. The Government-owned Nacional del Cobre de Chile (Codelco) produced about 85% of the country's copper production in 1978 and 1979. Codelco was carrying out major mine and mill expansion programs at the company's four divisions mainly to maintain production at current levels to counter the effects of decreasing ore grades. At Chuquicamata, Codelco's largest division, ore grades were expected to decline from 2.21% copper in 1980 to 1.65% copper by 1985 and to 1.25% by 1990. In the 5-year period through 1985, Codelco was planning to spend about $600 million to increase ore extraction and crushing facilities at the Chuquicamata open pit by 50%.

In January 1978 Exxon Minerals Corp. purchased the Los Bronces mine of Compânia Minera Dispulada de Las Condes for $107 million. In July 1978, an avalanche destroyed the concentrator bringing operations to a halt. Exxon rebuilt the concentrator for $4.5 million and resumed production in July 1979. Plans called for milling to be increased from 4,800 tons of ore per day to 8,500 tons by October 1980. Cia Minera El

Indio, 80% owned by St. Joe Minerals Corp., shipped the first ore from its gold-silver-copper ore body in northeastern Chile in August 1979. El Indio planned to ship ore until its concentrator was operational, expected in 1983.

In 1979 Anaconda bought the Los Pelambres deposit from the Government for $20 million. The company plans a 3-year exploration program to determine the feasibility of mining the deposit, which reportedly has reserves of about 430 million tons of ore averaging 0.78% copper.

China, mainland.—The Government planned to develop the copper reserves in Kiangsi, Anhui, and Hebei Provinces. Japanese and American companies were conducting feasibility studies. Sumitomo Metal Mining Co., Ltd. contracted to build a 90,000-ton-per-year smelter complex in Kiangsi Province. The smelter which was to eventually have its capacity increased to 200,000 tons of copper per year, was expected to be onstream in 1982. Plans called for the opening of seven mines to produce the necessary smelter concentrate feed.

Indonesia.—Freeport Indonesia Ltd. was developing for—$100 million—the Guung Bijih ore body near its Ertsberg East open pit mine. Plans called production at the new underground mine to be phased in beginning in late 1981 or early 1982 to coincide with the gradual phasing out of production from the nearby open pit mine, expected to close in 1984. Reserves in the new mine were estimated to 4.5 million tons grading 2.75% copper.

Iran.—Political events at the end of 1978 brought to a standstill operations and construction at the huge, Government owned, Sar Cheshmeh copper complex in southern Iran. The concentrator was 98% completed and the smelter was partially completed such that limited blister copper production was expected in January 1979. However owing to strikes and civil disruptions, all expatriate managers and technicians left the site bringing all work to a halt. No work on the project reportedly was carried out in 1979.

Mexico—The mine and mill portion of the $1 billion La Caridad copper project in Sonora, owned by Mexicana de Corbre, S.A., began production in May 1979. By June 1980 the company was expecting to produce at an annual rate of 600,000 tons of 32% copper concentrate, most of which was to be exported until a smelter was built. In June 1979 the company announced plans to build a $220 million smelter-refinery complex 22 kilometers north of Nacozari. Plans called for construction of a smelter to produce 180,000 ton per year of blister copper and a 150,000-ton-per-year electrolytic copper refinery, both to be operational in 1982. The smelter was to be designed to allow for eventually expansion to produce annually 225,000 tons of blister copper.

Papua New Guinea.—The Government accepted the American-Australian-West German consortium's report on with the development of the OK Tedi copper deposit in the Star Mountains in western Papua New Guinea. Plans called for construction at the site in early 1981 with production starting in 1985. Only gold would be produced from a gold-rich capping on the main ore body in the first few years after which the copper ore body, 300 million tons averaging 0.85% copper, would be brought into production.

Peru.—Copper production was at record levels in 1979 principally owing to production increases by Southern Peru Copper Corp. (SPCC), producer of about 75% of Peru's copper output. Although SPCC's nominal annual copper capacity totaled 272,000 tons, the company produced 291,000 tons of contained copper at its Toquepala and Cuajone mines in 1979.

Empresa Minera del Centro del Peru (Centromin), a government mining company, resumed the $177 million expansion of its Cobriza operations. The expansion, which had been delayed in 1978, was expected to result in a 400% increase in copper production by 1981.

Empresa Minera del Peru (Minero Peru), also a Government company, continued efforts to negotiate contracts for the the development of the Cerro Verde II copper project. In July 1979 Minero Peru (51%) and Geomin of Romania (49%) announced plans to invest about $539 million to develop the Antamina deposit to produce annually 89,200 tons of copper, 66,200 tons of zinc, 1,490 tons of molybdenum and 33.6 tons of silver. The project included construction of a $35 million 242 kilometer duct to transport copper and zinc concentrates from Huari to the port of Supe.

Philippines.—Copper production, although lower in 1978 owing in part to power shortages at some operations, reached record levels in 1979 due to the opening of new mines, several of which contain high gold values. The Government estimated that because of new mining operations and expansions at producing mines, the country's copper production would increase by about 50% in the next few years.

The Philippine Associated Smelting and Refining Corp. (PASAR) a joint venture of the Government and 11 copper companies, signed an agreement with a Japanese consortium for the construction of a $250 million, 138,000-ton-per-year smelter at Caima Bay on Leyete. The project was expected to be completed in 1983.

Benquet Consolidated Ltd. brought its $106 million Dizon gold-copper mine onstream in late 1979. Annual production at the mine was expected to total 19,000 tons copper, 100,000 troy ounces gold, and 220,000 troy ounces silver. Sabena Mining Corp. began production at its $85 million Kamanlagan mine on Mindanao in early 1979 and by yearend was producing at annual rate of 30,000 tons copper and 100,000 troy ounces gold in concentrate. The Basay mine (Negros Oriental Province) of the Construction and Development Corp. of the Philippines came fully onstream in June 1979 and was producing about 300 tons of copper concentrate per day most of which was exported to Japan.

South Africa, Republic of.—Palabora Mining Co., Ltd. attained higher production in 1978 and 1979 despite defective shells in the two autogenous mills installed in 1977. In August 1979 Palabora decided to proceed with further expansion of the open pit, deepening the pit by 100 meters and extending laterally 200 meters. The expansion would extend mine life by at least—5 years to 1997—and was expected to make available 625,000 tons of additional copper.

Zaire.—Copper production from the Government-owned La Generale des Carrieeres et des Mines du Zaire (Gecamines) was severely disrupted by the rebel invasion of Shaba Province in May 1978. Although Gecamines' output recovered to about 90% of its normal rate in the final month of 1978, copper output for the year fell about 68,000 tons. Although development programs to increase production were well advanced, the invasion and its after effects were delaying completion and resulting in significant cost increases. Production in 1979 declined another 45,000 tons owing to shortages of technical personnel, supplies, and fuel, and to continuing transportation problems. More than half of the Zairian copper exported in 1978 and 1979 was shipped through ports in the Republic of South Africa.

Zambia.—The Zambian copper industry continued to be hampered by severe transportation and production problems, loss of skilled and experienced labor, and a shortage of essential supplies. Low copper prices in 1978, lack of foreign exchange, and delayed importation of equipment and construction materials continued to cause deferment of some plant expansions and mine development. The inadequacy of traditional road and rail routes for export and import became critical in 1978, such that the Government reopened its rail link with Rhodesia in order to obtain critical supplies. Significant amounts of Zambian copper were exported through ports of the Republic of South Africa in 1978 and 1979.

Table 2.—Copper produced from domestic ores, by source

(Thousand metric tons)

Year	Mine	Smelter	Refinery
1975	1,282	1,247	1,167
1976	1,457	1,326	1,291
1977	1,364	1,265	1,280
1978	1,358	1,270	1,327
1979	1,444	1,313	1,412

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[1] Physical scientist, Section of Nonferrous Metals.

[2] The quantities used throughout this chapter are metric tons unless noted.

Table 3.—Copper ore and recoverable copper produced, by mining method

(Percent)

Year	Open pit		Underground	
	Ore	Copper[1]	Ore	Copper[2]
1975	89	80	11	20
1976	90	84	10	16
1977	90	83	10	17
1978	90	85	10	15
1979	88	84	12	16

[1] Includes copper from dump leaching.
[2] Includes copper from in-place leaching.

Table 4.—Mine production of recoverable copper in the United States, by month

(Metric tons)

Month	1978	1979
January	114,173	106,944
February	111,594	106,270
March	121,640	121,688
April	117,703	123,084
May	121,776	129,412
June	116,617	119,641
July	89,057	115,976
August	114,038	128,235
September	112,272	124,716
October	118,786	130,503
November	116,209	121,015
December	103,719	116,072
Total	1,357,586	1,443,556

Table 5.—Mine production of recoverable copper in the United States, by State

(Metric tons)

State	1975	1976	1977	1978	1979
Arizona	737,732	929,338	838,037	891,404	946,002
California	312	340	200	W	W
Colorado	3,230	2,205	1,720	1,191	362
Idaho	2,896	3,050	3,676	3,888	3,618
Maine	1,836	1,602	1,213	--	--
Michigan	66,850	39,650	38,442	W	W
Missouri	12,985	10,024	10,648	10,819	13,021
Montana	79,795	82,655	78,202	67,326	69,854
Nevada	73,673	52,762	60,837	20,453	W
New Mexico	132,687	156,362	149,412	127,828	164,281
Oregon	W	--	5	W	2
Pennsylvania	--	W	W	--	--
Tennessee	9,109	10,097	5,613	11,289	W
Utah	160,712	168,244	176,111	186,390	193,082
Other States[1]	416	231	250	37,057	53,335
Total[2]	1,282,184	1,456,561	1,364,374	1,357,586	1,443,556

W Withheld to avoid disclosing company proprietary data; included in "Other States."
[1] Includes Alaska, California, Michigan, Oregon, and Washington (1978); and California, Michigan, Nevada, Tennessee, and Washington (1979).
[2] Data may not add to totals shown because of independent rounding.

Table 6.—Twenty-five leading copper-producing mines in the United States in 1978, in order of output

Rank	Mine	County and State	Operator	Source of copper
1	Utah Copper	Salt Lake, Utah	Kennecott Copper Corp	Copper ore, copper precipitates.
2	Morenci	Greenlee, Ariz	Phelps Dodge Corp	Do.
3	San Manuel	Pinal, Ariz	Magma Copper Co	Copper ore, copper tailings.
4	Sierrita	Pima, Ariz	Duval Sierrita Corp	Copper ore.
5	Twin Buttes	do	Anamax Mining Co	Do.
6	Ray Pit	Pinal, Ariz	Kennecott Copper Corp	Copper ore, copper precipitates.
7	Tyrone	Grant, N. Mex	Phelps Dodge Corp	Do.
8	Berkeley Pit	Silver Bow, Mont	The Anaconda Company	Do.
9	Pinto Valley	Gila, Ariz	Cities Service Co	Do.
10	Metcalf	Greenlee, Ariz	Phelps Dodge Corp	Do.
11	Bagdad	Yavapai, Ariz	Cyprus Bagdad Copper Co	Copper ore.
12	Chino	Grant, N. Mex	Kennecott Copper Corp	Copper ore, copper precipitates.
13	New Cornelia	Pima, Ariz	Phelps Dodge Corp	Copper ore.
14	Mission	do	ASARCO Incorporated	Do.
15	Magma	Pinal, Ariz	Magma Copper Co	Do.
16	White Pine	Ontonagon, Mich	White Pine Copper Div	Do.
17	Inspiration	Gila, Ariz	Inspiration Consolidated Copper Co	Copper ore, copper precipitates.
18	Sacaton Unit	Pinal, Ariz	ASARCO Incorporated	Copper ore.
19	Silver Bell	Pima, Ariz	do	Copper ore, copper precipitates.
20	Mineral Park	Mohave, Ariz	Duval Corp	Do.
21	San Xavier Unit	Pima, Ariz	ASARCO Incorporated	Copper ore.
22	Copperhill (3 mines)	Polk, Tenn	Cities Service Co	Copper-zinc ore.
23	Yerington	Lyon, Nev	The Anaconda Company	Copper ore, copper precipitates.
24	Ruth Pit	White Pine, Nev	Kennecott Copper Corp	Copper ore.
25	Miami Unit	Gila, Ariz	Cities Service Co	Do.

Table 7.—Twenty-five leading copper-producing mines in the United States in 1979, in order of output

Rank	Mine	County and State	Operator	Source of copper
1	Utah Copper	Salt Lake, Utah	Kennecott Copper Corp	Copper ore, copper precipitates.
2	Morenci	Greenlee Ariz	Phelps Dodge Corp	Do.
3	Twin Buttes and Palo Verde	Pima, Ariz	Anamax Mining Co	Copper ore.
4	San Manuel	Pinal, Ariz	Magma Copper Co	Copper ore, copper tailings.
5	Tyrone	Grant, N. Mex	Phelps Dodge Corp	Copper ore, copper precipitates.
6	Sierrita	Pima, Ariz	Duval Corp	Copper ore.
7	Ray Pit	Pinal, Ariz	Kennecott Copper Corp	Copper ore, copper precipitates.
8	Berkeley Pit	Silver Bow, Mont	The Anaconda Company	Do.
9	Pinto Valley	Gila, Ariz	Cities Service Co	Do.
10	Bagdad	Yavapai, Ariz	Cyprus Bagdad Copper Co	Do.
11	Chino	Grant, N. Mex	Kennecott Copper Corp	Do.
12	Metcalf	Greenlee, Ariz	Phelps Dodge Corp	Do.
13	White Pine	Ontonagon, Mich	White Pine Copper Div	Copper ore.
14	New Cornelia	Pima, Ariz	Phelps Dodge Corp	Do.
15	Inspiration	Gila, Ariz	Inspiration Consolidated Copper Co	Copper ore, copper precipitates.
16	Magma	Pinal, Ariz	Magma Copper Co	Copper ore.
17	Mission	Pima, Ariz	ASARCO Incorporated	Do.
18	Silver Bell	do	do	Copper ore, copper precipitates.
19	Sacaton Unit	Pinal, Ariz	do	Copper ore.
20	Continental	Grant, N. Mex	UV Industries, Inc	Do.
21	Esperanza	Pima, Ariz	Duval Corp	Copper ore, copper precipitates.
22	Mineral Park	Mohave, Ariz	do	Do.
23	Copperhill (3 mines).	Polk, Tenn	Cities Service Co	Copper-zinc ore.
24	Pima	Pinal, Ariz	Cyprus Pima Mining Co	Copper ore.
25	Miami Unit	Gila, Ariz	Cities Service Co	Do.

Table 8.—Mine production of recoverable copper in 1978, by method of treatment

Method of treatment	Ore treated (thousand metric tons)	Recoverable copper		Remarks
		Metric tons	Percent yield	
Copper ore:				
By concentration	224,893	1,126,660	0.50	See table 12.
By smelting	258	573	.22	See table 14.
By leaching	14,096	102,063	.72	See table 16.
Total or average	239,247	1,229,296	.51	
Tailings, dump, in-place material by leaching	--	111,164	--	See table 16.
Miscellaneous from cleanup, tailings, noncopper ores	--	17,126	--	
Total	XX	1,257,586	XX	--

XX Not applicable.

Table 9.—Mine production of recoverable copper in 1979, by method of treatment

Method of treatment	Ore treated (thousand metric tons)	Recoverable copper		Remarks
		Metric tons	Percent yield	
Copper ore:				
By concentration	248,722	1,208,731	0.49	See table 13.
By smelting	199	598	.30	See table 15.
By leaching	15,869	88,501	.56	See table 17.
Total or average	264,790	1,297,830	.49	
Tailings, dump, in-place material by leaching	--	126,514	--	See table 17.
Miscellaneous from cleanup, tailings, noncopper ores	--	19,211	--	
Total	XX	[1]1,443,556	XX	--

XX Not applicable.

[1] Data do not add to total shown because of independent rounding.

Table 10.—Copper ore shipped directly to smelters or concentrated in the United States, by State in 1978, with copper, gold, and silver content in terms of recoverable metal

State	Ore shipped or concentrated (thousand metric tons)	Recoverable metal content				Value of gold and silver per metric ton of ore
		Copper		Gold (troy ounces)	Silver (troy ounces)	
		Metric tons	Percent			
Arizona	149,331	729,718	0.49	92,507	6,611,722	$0.36
Montana	16,229	64,097	.39	16,949	2,281,180	.96
Nevada	2,254	10,436	.46	W	232,461	W
New Mexico	19,799	108,957	.55	W	757,175	W
Tennessee[1]	1,837	11,289	.61	W	W	W
Utah	32,602	165,441	.51	W	W	W
Other States[2]	3,098	37,294	1.20	257,717	2,617,302	1.16
Total or average[3]	225,151	1,127,233	.50	367,173	12,499,840	.62

W Withheld to avoid disclosing company proprietary data; included in "Other States."

[1] Copper-zinc ore.

[2] Includes data for Alaska, Idaho, Michigan, Nevada, New Mexico, Tennessee, Utah, and Washington.

[3] Data may not add to totals shown because of independent rounding.

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Table 11.—Copper ore shipped directly to smelters or concentrated in the United States, by State in 1979, with copper, gold, and silver content in terms of recoverable metal

State	Ore shipped or concentrated (thousand metric tons)	Recoverable metal content				Value of gold and silver per metric ton of ore
		Copper		Gold (troy ounces)	Silver (troy ounces)	
		Metric tons	Percent			
Arizona	169,177	779,908	0.46	99,542	7,451,824	$0.67
Montana	15,533	62,227	.40	21,356	2,657,847	2.32
New Mexico	24,605	144,444	.59	19,284	1,285,572	.82
Utah	34,346	171,842	.50	W	W	W
Other States[1] [2]	5,260	50,908	.96	251,176	2,791,756	2.78
Total or average	248,921	1,209,329	.49	391,358	14,186,999	1.12

W Withheld to avoid disclosing company proprietary data; included in "Other States."

[1] Includes data for Idaho, Michigan, Nevada, Tennessee, and Utah.

[2] Includes copper-zinc ore.

Table 12.—Copper ore concentrated[1] in the United States, by State in 1978, with content in terms of recoverable copper

State	Ore concentrated (thousand metric tons)	Recoverable copper content	
		Metric tons	Percent
Arizona	149,148	729,298	0.49
Montana	16,229	64,097	.39
Nevada	2,227	10,302	.46
New Mexico	19,751	108,940	.55
Tennessee[2]	1,887	11,289	.61
Utah	32,602	165,441	.51
Other	3,098	37,293	1.20
Total or average	[3]224,893	1,126,660	.50

[1] Includes following methods of concentration: "Dual process" (leaching followed by concentration); "LPF" (leach-precipitation-flotation); and froth flotation.

[2] Copper-zinc ore.

[3] Data do not add to total shown because of independent rounding.

Table 13.—Copper ore concentrated[1] in the United States, by State in 1979, with content in terms of recoverable copper

State	Ore concentrated (thousand metric tons)	Recoverable copper content	
		Metric tons	Percent
Arizona	169,035	779,448	0.46
New Mexico	24,550	144,423	.59
Other States	55,137	284,860	.52
Total or average	248,722	1,208,731	.49

[1] Includes following methods of concentration: "Dual process" (leaching followed by concentration); "LPF" (leach-precipitation-flotation); and froth flotation.

Table 14.—Copper ore shipped directly to smelters[1] in the United States, by State in 1978, with content in terms of recoverable copper

State	Ore shipped to smelters		
	Metric tons	Recoverable copper content	
		Metric tons	Percent
Arizona	182,320	420	0.23
Nevada	27,385	135	.49
New Mexico	48,201	17	.04
Other States	4	1	18.11
Total or average	257,910	573	.22

[1] Primarily smelter fluxing material.

Table 15.—Copper ore shipped directly to smelters[1] in the United States, by State in 1979, with content in terms of recoverable copper

State	Ore shipped to smelters		
	Metric tons	Recoverable copper content	
		Metric tons	Percent
Arizona	142,373	460	0.32
New Mexico	55,194	21	.04
Other States	1,222	117	9.56
Total or average	198,789	598	.30

[1] Primarily smelter fluxing material.

Table 16.—Copper precipitates (leached from dump and in-place material or tailings) shipped directly to smelters, and copper ore leached (heap, vat, or tank) in the United States, by State in 1978, with content in terms of recoverable copper

State	Precipitates shipped (metric tons)	Recoverable copper content (metric tons)	Ore leached (metric tons)	Recoverable copper content (metric tons)	Percent
Arizona	100,010	[1]66,861	[2]12,330,292	94,762	0.77
Montana	3,867	2,675	--	--	--
Nevada	3,755	2,713	1,765,960	7,301	.41
New Mexico	25,007	18,649	--	--	--
Utah	24,538	20,266	--	--	--
Total or average	157,177	111,164	[3]14,096,251	102,063	.72

[1] Includes copper from newly generated tailings.

[2] Includes 5,264,808 metric tons of ore leached for electrowinning.

[3] Data do not add to total shown because of independent rounding.

Table 17.—Copper precipitates (leached from dump and in-place material or tailings) shipped directly to smelters, and copper ore leached (heap, vat, or tank) in the United States, by State in 1979, with content in terms of recoverable copper

State	Precipitates shipped (metric tons)	Recoverable copper content (metric tons)	Ore leached (metric tons)	Recoverable copper content (metric tons)	Percent
Arizona	128,423	[1]77,437	[2]15,869,243	88,501	0.56
New Mexico	[3]21,280	[4]19,826	W	W	W
Utah	26,360	20,944	--	--	--
Other States	13,279	8,307	--	--	--
Total or average	189,342	126,514	15,869,243	88,501	0.56

W Withheld to avoid disclosing company proprietary data.

[1] Includes copper from newly generated tailings.

[2] Includes 8,170,077 metric tons of ore leached for electrowinning.

[3] Includes small amount of ore leached.

[4] Includes small amount of copper recovered from ore leached.

Table 18.—Copper ore smelted and copper ore concentrated in the United States, and average yield in copper, gold, and silver

Year	Smelting ore		Concentrating ore		Total				
	Thousand metric tons	Yield in copper (percent)	Thousand metric tons[1] [2]	Yield in copper (percent)	Thousand metric tons[2]	Yield in copper (percent)	Yield per metric ton in gold (ounce)	Yield per metric ton in silver (ounce)	Value per metric ton in gold and silver
1975	324	1.85	217,374	0.48	238,592	0.47	0.0015	0.056	$0.48
1976	236	.32	234,391	.50	257,401	.51	.0014	.058	.43
1977	272	.31	217,861	.51	235,844	.52	.0016	.061	.52
1978	255	.22	224,893	.50	239,247	.51	.0016	.056	.62
1979	199	.30	248,722	.49	264,790	.49	.0016	.057	1.12

[1] Includes some ore classed as copper-zinc and minor amount of tailings.

[2] Excludes tank or vat and heap leaching. (See tables 8, 9, 16, and 17.)

Table 19.—Copper produced by primary smelters in the United States

(Metric tons)

Year	Domestic	Foreign	Secondary	Total
1975	1,246,766	66,047	44,776	1,357,589
1976	1,325,629	66,557	46,307	1,438,493
1977	1,265,008	36,962	44,846	1,346,816
1978	1,269,981	18,397	54,216	1,342,594
1979	1,313,224	22,383	60,231	1,395,838

Table 20.—Primary and secondary copper produced by primary refineries and electrowinning plants in the United States

(Metric tons)

	1975	1976	1977	1978	1979
PRIMARY					
From domestic ores, etc.:[1]					
Electrolytic	1,034,875	1,107,800	1,052,505	1,124,585	1,207,626
Electrowon	28,097	94,294	126,512	98,416	98,801
Fire refined	103,839	88,579	101,018	104,272	105,091
Total	1,166,811	1,290,673	1,280,035	1,327,273	1,411,518
From foreign ores, etc.:[1]					
Electrolytic[2]	142,600	105,764	77,281	121,684	103,858
Electrowon	W	W	W	W	W
Fire refined	W	--	W	W	W
Total refinery production of primary copper	1,309,411	1,396,437	1,357,316	1,449,057	1,515,376
SECONDARY					
Electrolytic[2]	240,779	254,983	240,552	293,437	298,344
Electrowon	W	W	W	W	W
Fire refined	4,959	6,909	W	W	W
Total secondary	245,738	261,892	240,552	293,437	298,344
Grand total	1,555,149	1,658,329	1,597,868	1,742,494	1,813,720

W Withheld to avoid disclosing company proprietary data; included in "Electrolytic."

[1] The separation of refined copper into metal of domestic and foreign origin is only approximate, as accurate separation is not possible at this stage of processing.

[2] Includes electrowon and fire refined quantities indicated by symbol W.

Table 21.—Copper cast in forms at primary refineries in the United States

	1978		1979	
	Thousand metric tons	Percent	Thousand metric tons	Percent
Billets	54	3	57	3
Cakes	84	5	93	5
Cathodes	942	54	968	54
Ingots and ingot bars	104	6	78	4
Wire bars	521	30	580	32
Other forms	37	2	38	2
Total	1,742	100	1,814	100

Table 22.—Production, shipments, and stocks of copper sulfate

(Metric tons)

Year	Production		Shipments[1]	Stocks Dec. 31
	Quantity	Copper content		
1975	32,306	8,350	28,868	6,229
1976	29,141	7,629	27,807	7,763
1977	27,306	7,199	28,084	6,985
1978	31,861	8,551	31,306	7,656
1979	35,866	9,286	33,962	8,661

[1] Includes consumption by producing companies.

Table 23.—Byproduct sulfuric acid[1] (100% basis) produced in the United States

(Metric tons)

Year	Copper plants[2]	Lead plants	Zinc plants[3]	Total
1975	1,619,093	117,713	645,706	2,382,512
1976	2,069,825	182,333	725,542	2,977,700
1977	2,138,567	127,898	669,304	2,935,769
1978	2,484,111	202,935	686,275	3,373,321
1979	2,513,035	282,704	773,836	3,569,575

[1] Includes acid from foreign materials.
[2] Excludes acid made from pyrite concentrates.
[3] Excludes acid made from native sulfur.

Table 24.—Secondary copper produced in the United States

(Metric tons)

	1975	1976	1977	1978	1979
Copper recovered as unalloyed copper	322,515	354,463	364,721	437,120	516,271
Copper recovered in alloys[1]	559,237	684,512	720,704	810,115	1,036,254
Total secondary copper[1]	881,752	1,038,975	1,085,425	1,247,235	1,552,525
Source:					
New scrap	546,844	658,750	675,497	745,585	948,224
Old scrap	334,908	380,225	409,928	501,650	604,301
Percentage equivalent of domestic mine output	69	71	80	92	108

[1] Includes copper in chemicals, as follows: 1975—2,248; 1976—3,635; 1977—3,283; 1978—2,911; and 1979—3,004.

Table 25.—Copper recovered from scrap processed in the United States by kind of scrap and form of recovery

(Metric tons)

	1978	1979
Kind of scrap		
New scrap:		
Copper-base	724,856	926,025
Aluminum-base	20,471	21,937
Nickel-base	233	237
Zinc-base	25	25
Total	745,585	948,224
Old scrap:		
Copper-base	486,298	587,935
Aluminum-base	15,046	16,181
Nickel-base	232	121
Tin-base	8	5
Zinc-base	66	59
Total	501,650	604,301
Grand total	1,247,235	1,552,525
Form of recovery		
As unalloyed copper:		
At primary plants	293,437	298,344
At other plants	143,683	217,927
Total	437,120	516,271
In brass and bronze	755,978	976,402
In alloy iron and steel	2,840	3,096
In aluminum alloys	48,153	53,606
In other alloys	224	154
In chemical compounds	2,911	3,004
Total	810,115	1,036,254
Grand total	1,247,235	1,552,525

Table 26.—Copper recovered as refined copper, in alloys and in other forms from copper-base scrap processed in the United States

(Metric tons)

Recovered by—	From new scrap		From old scrap		Total	
	1978	1979	1978	1979	1978	1979
Secondary smelters	111,998	242,517	241,644	346,280	353,642	588,797
Primary copper producers	126,822	139,636	166,615	158,708	293,437	298,344
Brass mills	462,792	520,413	28,607	31,201	491,399	551,614
Foundries and manufacturers	21,096	21,334	48,669	50,867	69,765	72,201
Chemical plants	2,148	2,125	763	879	2,911	3,004
Total	724,856	926,025	486,298	587,935	1,211,154	1,513,960

Table 27.—Production of secondary copper and copper-alloy products in the United States

(Metric tons)

Item produced from scrap	1978	1979
UNALLOYED COPPER PRODUCTS		
Refined copper by primary producers	293,437	298,344
Refined copper by secondary smelters	126,666	200,115
Copper powder	16,992	17,411
Copper castings	25	401
Total	437,120	516,271
ALLOYED COPPER PRODUCTS		
Brass and bronze ingots:		
Tin bronzes	21,831	21,964
Leaded red brass and semired brass	135,162	136,416
High-leaded tin bronze	24,806	26,449
Yellow brass	11,950	12,488
Manganese bronze	10,778	10,277
Aluminum bronze	7,193	7,684
Nickel silver	2,922	3,113
Silicon bronze and brass	4,339	4,527
Copper-base hardeners and master alloys	19,257	18,135
Total	238,238	241,053
Brass-mill products	624,091	692,136
Brass and bronze castings	51,914	51,555
Brass powder	1,243	1,197
Copper in chemical products	2,911	3,004
Grand total	1,355,517	1,505,216

Table 28.—Composition of secondary copper-alloy production

(Metric tons)

	Copper	Tin	Lead	Zinc	Nickel	Aluminum	Total
Brass and bronze production:[1]							
1978	186,461	11,218	17,418	22,710	383	48	238,238
1979	216,135	4,513	9,566	10,281	479	79	241,053
Secondary metal content of brass-mill products:							
1978	491,399	438	3,405	126,826	1,999	24	624,091
1979	551,614	471	3,658	133,588	2,778	27	692,136
Secondary metal content of brass and bronze castings:							
1978	42,206	1,441	3,125	5,095	17	30	51,914
1979	42,110	1,423	3,166	4,750	47	59	51,555

[1] About 91% from scrap and 9% from other than scrap (1978); and about 95% from scrap and 5% from other than scrap (1979).

Table 29.—Stocks and consumption of purchased copper scrap in the United States in 1978

(Metric tons)

Class of consumer and type of scrap	Stocks Jan. 1	Receipts	Consumption			Stocks Dec. 31
			New scrap	Old scrap	Total	
SECONDARY SMELTERS						
No. 1 wire and heavy copper	2,783	27,653	4,387	24,387	28,774	1,662
No. 2 wire, mixed heavy and light copper	6,680	128,851	44,273	84,616	128,889	6,642
Composition or red brass	4,331	62,049	14,027	48,954	62,981	3,399
Railroad-car boxes	231	2,367	--	2,455	2,455	143
Yellow brass	7,223	41,450	5,540	38,506	44,046	4,627
Cartridge cases and brass	64	57	--	96	96	25
Auto radiators (unsweated)	4,180	73,368	--	73,444	73,444	4,104
Bronze	1,873	17,150	2,851	14,538	17,389	1,634
Nickel silver and cupronickel	759	2,339	345	2,313	2,658	440
Low brass	530	2,842	1,088	1,951	3,039	333
Aluminum bronze	130	447	236	129	365	212
Low-grade scrap and residues	16,355	121,569	100,977	25,489	126,466	11,458
Total	45,139	480,142	173,724	316,878	490,602	34,679
PRIMARY PRODUCERS						
No. 1 wire and heavy copper	9,518	94,108	47,482	52,740	100,222	3,404
No. 2 wire, mixed heavy and light copper	11,381	145,774	72,740	75,514	148,254	8,901
Refinery brass	14,739	2,524	216	2,077	2,293	25,048
Low-grade scrap and residues		186,945	48,493	128,374	176,867	
Total	35,638	429,351	168,931	258,705	427,636	37,353
BRASS MILLS[1]						
No. 1 wire and heavy copper	12,687	168,534	140,244	28,290	168,534	9,492
No. 2 wire, mixed heavy and light copper	7,343	39,579	38,506	1,073	39,579	5,037
Yellow brass	24,744	277,189	277,189	--	277,189	21,962
Cartridge cases and brass	12,664	82,756	82,752	4	82,756	9,720
Bronze	722	5,234	5,234	--	5,234	598
Nickel silver and cupronickel	2,406	16,119	16,119	--	16,119	2,769
Low brass	3,516	48,288	48,288	--	48,288	3,037
Aluminum bronze	39	243	243	--	243	30
Total[1]	64,121	637,942	608,575	29,367	637,942	52,645
FOUNDRIES, CHEMICAL PLANTS, AND OTHER MANUFACTURERS						
No. 1 wire and heavy copper	2,468	35,035	11,530	22,850	34,380	3,123
No. 2 wire, mixed heavy and light copper	855	9,427	4,478	4,912	9,390	892
Composition or red brass	333	11,384	1,937	9,337	11,274	443
Railroad-car boxes	802	7,415	--	7,342	7,342	875
Yellow brass	456	11,558	7,472	4,072	11,544	470
Auto radiators (unsweated)	1,119	9,666	--	10,009	10,009	776
Bronze	913	696	259	417	676	933
Nickel silver and cupronickel	10	114	110	7	117	7
Low brass	87	1,706	1,641	89	1,730	63
Aluminum bronze	55	336	33	300	333	58
Low-grade scrap and residues	8	8	--	4	4	12
Total	7,106	87,345	[2]27,460	[2]59,339	86,799	7,652
GRAND TOTAL						
No. 1 wire and heavy copper	27,456	325,330	203,643	128,267	331,910	17,681
No. 2 wire, mixed heavy and light copper	26,259	323,631	159,997	166,115	326,112	21,472
Composition or red brass	4,664	73,433	15,964	58,291	74,255	3,842
Railroad-car boxes	1,033	9,782	--	9,797	9,797	1,018
Yellow brass	32,423	330,197	290,201	42,578	332,779	27,059
Cartridge cases and brass	12,728	82,813	82,752	100	82,852	9,745
Auto radiators (unsweated)	5,299	83,034	--	83,453	83,453	4,880
Bronze	3,508	23,080	8,344	14,955	23,299	3,165
Nickel silver and cupronickel	3,175	18,572	16,574	2,320	18,894	3,216
Low brass	4,133	52,836	51,017	2,040	53,057	3,433
Aluminum bronze	224	1,026	512	429	941	300
Low-grade scrap and residues[3]	31,102	311,046	149,686	155,944	305,630	36,518
Total	152,004	1,634,780	978,690	664,289	1,642,979	132,329

[1] Brass-mill stocks include home scrap; purchased scrap consumption assumed equal to receipts, so lines in brass-mill and grand total sections do not balance.

[2] Of the totals shown, chemical plants reported the following: Unalloyed copper scrap, 2,256 tons new and 794 tons old.

[3] Includes refinery brass.

Table 30.—Stocks and consumption of purchased copper scrap in the United States in 1979

(Metric tons)

Class of consumer and type of scrap	Stocks Jan. 1	Receipts	Consumption			Stocks Dec. 31
			New scrap	Old scrap	Total	
SECONDARY SMELTERS						
No. 1 wire and heavy copper	1,662	59,950	5,990	53,518	59,508	2,104
No. 2 wire, mixed heavy and light copper	6,642	235,506	115,445	115,073	230,518	11,630
Composition or red brass	3,399	66,727	13,128	54,804	67,932	2,194
Railroad-car boxes	143	1,821	--	1,770	1,770	194
Yellow brass	4,627	46,178	5,789	41,248	47,037	3,768
Cartridge cases and brass	25	109	--	62	62	72
Auto radiators (unsweated)	4,104	84,474	--	84,976	84,976	3,602
Bronze	1,634	18,255	3,304	14,998	18,302	1,587
Nickel silver and cupronickel	440	3,629	500	2,964	3,464	605
Low brass	333	3,439	1,264	2,063	3,327	445
Aluminum bronze	212	610	576	100	676	146
Low-grade scrap and residues	11,458	278,370	203,857	73,783	277,640	12,188
Total	34,679	799,068	349,853	445,359	795,212	38,535
PRIMARY PRODUCERS						
No. 1 wire and heavy copper	3,404	106,892	43,385	57,519	100,904	8,392
No. 2 wire, mixed heavy and light copper	8,901	153,123	93,446	62,597	156,043	10,981
Refinery brass	25,048	5,823	75	5,810	5,885	18,734
Low-grade scrap and residues		216,961	57,195	166,018	223,213	
Total	37,353	486,799	194,101	291,944	486,045	38,107
BRASS MILLS[1]						
No. 1 wire and heavy copper	9,492	194,951	164,823	30,128	194,951	11,794
No. 2 wire, mixed heavy and light copper	5,037	50,647	49,290	1,357	50,647	2,846
Yellow brass	21,962	295,843	295,843	--	295,843	21,600
Cartridge cases and brass	9,720	80,458	80,394	64	80,458	10,519
Bronze	598	5,418	5,418	--	5,418	480
Nickel silver and cupronickel	2,769	24,857	24,857	--	24,857	3,670
Low brass	3,037	50,693	50,693	--	50,693	3,012
Aluminum bronze	30	271	271	--	271	19
Total[1]	52,645	703,138	671,589	31,549	703,138	53,940
FOUNDRIES, CHEMICAL PLANTS, AND OTHER MANUFACTURERS						
No. 1 wire and heavy copper	3,123	37,014	11,193	25,556	36,749	3,388
No. 2 wire, mixed heavy and light copper	892	9,853	5,296	4,763	10,059	686
Composition or red brass	443	12,826	3,647	8,925	12,572	697
Railroad-car boxes	875	6,985	--	7,153	7,153	707
Yellow brass	470	11,098	6,426	4,709	11,135	433
Auto radiators (unsweated)	776	9,051	--	9,147	9,147	680
Bronze	933	821	518	336	854	900
Nickel silver and cupronickel	7	131	11	117	128	10
Low brass	63	347	229	128	357	53
Aluminum bronze	58	680	28	630	658	90
Low-grade scrap and residues	12	7	--	19	19	--
Total	7,652	88,813	[2]27,348	[2]61,483	88,831	7,634
GRAND TOTAL						
No. 1 wire and heavy copper	17,681	397,807	225,391	166,721	392,112	25,678
No. 2 wire, mixed heavy and light copper	21,472	454,129	263,477	183,790	447,267	26,148
Composition or red brass	3,842	79,553	16,775	63,729	80,504	2,891
Railroad-car boxes	1,018	8,806	--	8,923	8,923	901
Yellow brass	27,059	353,119	308,058	45,957	354,015	25,801
Cartridge cases and brass	9,745	80,567	80,394	126	80,520	10,591
Auto radiators (unsweated)	4,880	93,525	--	94,123	94,123	4,282
Bronze	3,165	24,494	9,240	15,334	24,574	2,967
Nickel silver and cupronickel	3,216	28,617	25,368	3,081	28,449	4,285
Low brass	3,433	54,479	52,186	2,191	54,377	3,510
Aluminum bronze	300	1,561	875	730	1,605	245
Low-grade scrap and residues[3]	36,518	501,161	261,127	245,630	506,757	30,922
Total	132,329	2,077,818	1,242,891	830,335	2,073,226	138,216

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[1] Brass-mill stocks include home scrap; purchased scrap consumption assumed equal to receipts, so lines in brass-mill and grand total sections do not balance.

[2] Of the totals shown, chemical plants reported the following: Unalloyed copper scrap, 2,236 tons new and 915 tons old.

[3] Includes refinery brass.

Table 31.—Consumption of copper and brass materials in the United States by principal consuming groups

(Metric tons)

Year and item	Primary producers	Brass mills	Wire rod mills	Foundries, chemical plants, and miscellaneous users	Secondary smelters	Total
1978:						
Copper scrap	427,636	637,942	--	86,799	490,602	1,624,979
Refined copper[1]	--	619,206	1,517,413	45,208	7,474	2,189,301
Brass ingot	--	6,776	--	[2]226,354	--	233,130
Slab zinc	--	128,006	--	2,367	11,115	141,488
Miscellaneous	--	--	--	180	3,723	3,903
1979:						
Copper scrap	486,045	703,138	--	88,831	795,212	2,073,226
Refined copper[1]	--	610,177	1,499,596	42,418	6,251	2,158,442
Brass ingot	--	4,050	--	[2]237,444	--	241,494
Slab zinc	--	127,628	--	2,770	11,006	141,404
Miscellaneous	--	--	--	180	--	180

[1] Detailed information on consumption of refined copper will be found in table 36.

[2] Shipments to foundries by smelters and change in stocks at foundries.

Table 32.—Foundry consumption of brass ingot, by types, in the United States

(Metric tons)

	1975	1976	1977	1978	1979
Tin bronzes	37,177	30,043	34,649	35,951	35,242
Leaded red brass and semired brass	76,962	88,661	97,095	106,053	107,596
Yellow brass	59,694	21,016	23,841	21,308	21,138
Manganese bronze	6,210	5,166	5,296	7,490	7,724
Hardeners and master alloys	4,009	3,071	3,484	4,398	5,913
Nickel silver	2,212	2,040	2,096	2,330	2,315
Aluminum bronze	4,794	5,274	6,122	7,071	7,267
Total	191,058	155,271	172,583	184,601	187,195

Table 33.—Foundry consumption of brass ingot by type, refined copper, and copper scrap, in the United States in 1978, by geographic division and State

(Metric tons)

Geographic division and State	Tin bronzes	Leaded red brass and semi-red brass	Yellow brass	Manganese bronze	Hardeners and master alloys	Nickel silver	Aluminum bronze	Total brass ingot	Refined copper consumed	Copper scrap consumed
New England:										
Connecticut	573	1,750	1,275					4,390	400	638
Massachusetts	1,051	2,087	619	184	665	306	229	4,125	935	76
Maine, New Hampshire, Rhode Island, Vermont	248	2,086	114	413				3,095		
Total	1,872	5,923	2,008	597	665	306	229	11,610	1,335	714
Middle Atlantic:										
New Jersey	559	1,125	233	1,121	1,136	463	98	2,212	4,085	7,171
New York	941	7,881	1,040				59	10,954		
Pennsylvania	7,149	5,960	1,839	442			1,768	18,648	4,609	5,647
Total	8,649	14,966	3,112	1,563	1,136	463	1,925	31,814	8,694	12,818
East North Central:										
Illinois	5,661	12,277	849	629	1,209	224	1,013	16,296	727	1,664
Indiana		6,983	461	229			36	13,225	756	9,795
Michigan	320	4,765	490	1,455			451	7,530	8,682	3,151
Ohio	10,579	10,294	3,575	907	1,092	351	458	25,904	8,482	9,811
Wisconsin	1,751	5,552	2,280	117			235	11,258		3,673
Total	18,311	39,871	7,655	3,337	2,301	575	2,193	74,243	18,647	28,094

See footnotes at end of table.

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Table 33.—Foundry consumption of brass ingot by type, refined copper, and copper scrap, in the United States in 1978, by geographic division and State—Continued

(Metric tons)

Geographic division and State	Tin bronze	Leaded red brass and semi-red brass	Yellow brass	Manganese bronze	Hardeners and master alloys	Nickel silver	Aluminum bronze	Total brass ingot	Refined copper consumed	Copper scrap consumed
West North Central:										
Iowa, Kansas, Minnesota	181	4,374	1,503	286	82	10	654	6,548	3,379	10,315
Missouri, Nebraska, South Dakota	190	1,567	1,086	153				3,538		
Total	371	5,941	2,589	439	82	10	654	10,086	3,379	10,315
South Atlantic:										
Delaware, District of Columbia, Florida, Georgia, Maryland	465	363	536	80	3	700	64	1,766	2,887	4,916
North Carolina, South Carolina, Virginia, West Virginia	117	6,432		55			234	7,283		
Total	582	6,795	536	135	3	700	298	9,049	2,887	4,916
East South Central:										
Alabama, Kentucky, Mississippi, Tennessee	1,944	12,346	2,187	541			1,308	17,381		7,979
West South Central:										
Arkansas, Louisiana, Oklahoma, Texas	2,330	7,940	1,262	182	143	194		12,984	9,069	2,558
Mountain:										
Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah	291	478	234	41			46	1,092		547
Pacific:										
California	1,463	11,703	1,785	500	68	82	408	15,854	750	13,639
Oregon and Washington	148	90		95				488		2,260
Total	1,611	11,793	1,785	595	68	82	408	16,342	750	15,899
Grand total	35,951	106,053	21,368	7,430	4,398	2,330	7,071	184,601	44,761	83,750

Table 34.—Foundry consumption of brass ingot by type, refined copper, and copper scrap, in the United States in 1979, by geographic division and State

(Metric tons)

Geographic division and State	Tin bronzes	Leaded red brass and semi-red brass	Yellow brass	Manganese bronze	Hardeners and master alloys	Nickel silver	Aluminum bronze	Total brass ingot	Refined copper consumed	Copper scrap consumed
New England:										
Connecticut	841	2,143	1,126	24	704	309	369	5,004	309	675
Massachusetts	621	1,777	649	189				3,348	907	171
Maine, New Hampshire, Rhode Island, Vermont	290	1,967		421				3,078		
Total	1,752	5,887	1,775	634	704	309	369	11,430	1,216	846
Middle Atlantic:										
New Jersey	881	961	129	143	1,257	426	74	2,232	4,228	7,118
New York	912	7,767	1,112	692			111	10,651		
Pennsylvania	6,995	5,841	1,632	530			1,601	18,181	4,246	5,632
Total	8,788	14,569	2,873	1,365	1,257	426	1,786	31,064	8,474	12,750
East North Central:										
Illinois	5,824	13,552	893	659	1,613	108	1,363	17,592	1,210	2,112
Indiana		7,196	329	219			43	14,179		9,368
Michigan	292	4,091	477	1,539			461	6,956	6,835	3,246
Ohio	11,636	10,378	6,348	945	1,435	277	411	25,613	7,991	9,009
Wisconsin		6,047		167			201	12,158		4,258
Total	17,752	41,264	8,047	3,529	3,048	385	2,479	76,498	16,036	27,992

See footnotes at end of table.

Table 34.—Foundry consumption of brass ingot by type, refined copper, and copper scrap, in the United States in 1979, by geographic division and State—Continued

(Metric tons)

Geographic division and State	Tin bronze	Leaded red brass and semi-red brass	Yellow brass	Manganese bronze	Hardeners and master alloys	Nickel silver	Aluminum bronze	Total brass ingot	Refined copper consumed	Copper scrap consumed
West North Central:										
Iowa, Kansas, Minnesota	120	3,215	2,117	518	144	16	127	5,293	3,099	10,053
Missouri, Nebraska, South Dakota	65	1,745		142			373	3,289		
Total	185	4,960	2,117	660	144	16	500	8,582	3,099	10,053
South Atlantic:										
Delaware, District of Columbia, Florida, Georgia, Maryland	493	441	531	87	3	868	116	2,100	2,856	6,520
North Carolina, South Carolina, Virginia, West Virginia	99	7,926		82			384	8,930		
Total	592	8,367	531	169	3	868	500	11,030	2,856	6,520
East South Central:										
Alabama, Kentucky, Mississippi, Tennessee	2,079	12,021	2,379	518	109	225	36	17,298	8,864	8,471
West South Central:										
Arkansas, Louisiana, Oklahoma, Texas	2,201	9,363	1,215	211			1,174	14,271		3,739
Mountain:										
Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah	264	430	287	40			29	1,052		636
Pacific:										
California	1,474	10,629	1,914	604	648	86	394	14,835	868	12,300
Oregon and Washington	155	106						1,175		2,323
Total	1,629	10,735	1,914	604	648	86	394	16,010	868	14,623
Grand total	35,242	107,896	21,136	7,724	5,918	2,315	7,287	197,196	42,008	85,680

Table 35.—Primary refined copper supply and withdrawals on domestic account

(Metric tons)

	1975	1976	1977	1978	1979
Production from domestic and foreign ores, etc.	1,309,411	1,296,437	1,357,316	1,449,057	1,515,376
Imports[1]	133,179	346,113	354,506	414,697	215,161
Stocks Jan. 1[1]	92,000	187,000	172,000	212,000	153,000
Total available supply	1,534,590	1,829,550	1,883,822	2,075,754	1,883,537
Copper exports[1]	156,422	101,502	46,745	91,923	73,677
Stocks Dec. 31[1]	187,000	172,000	212,000	153,000	64,000
Total	343,422	273,502	258,745	244,923	137,677
Apparent withdrawals on domestic account[2]	1,191,000	1,556,000	1,625,000	1,831,000	1,746,000

[1] May include some copper refined from scrap.

[2] Excludes copper, if any, delivered to industry from national stockpile sales.

Table 36.—Refined copper consumed by class of consumer

(Metric tons)

Year and class	Cathodes	Wire bars	Ingots and ingot bars	Cakes and slabs	Billets	Other	Total
1978:							
Wire rod mills	748,606	761,471	W	--	--	7,336	1,517,413
Brass mills	260,954	33,203	93,377	117,114	114,558	--	619,206
Chemical plants	--	--	--	--	--	447	447
Secondary smelters	3,328	--	4,146	--	--	--	7,474
Foundries	2,703	W	8,393	--	W	1,335	12,431
Miscellaneous[1]	10,550	W	6,025	W	W	15,755	32,330
Total	1,026,141	794,674	111,941	117,114	114,558	24,873	2,189,301
1979:							
Wire rod mills	812,345	673,575	W	W	--	13,676	1,499,596
Brass mills	272,059	28,335	74,333	105,573	129,462	415	610,177
Chemical plants	--	--	--	--	--	415	415
Secondary smelters	2,052	--	4,039	--	--	160	6,251
Foundries	2,618	W	7,898	--	W	1,402	11,918
Miscellaneous[1]	9,945	W	5,813	W	W	14,327	30,085
Total	1,099,019	701,910	92,083	105,573	129,462	30,395	2,158,442

W Withheld to avoid disclosing company proprietary data; included in "Other."

[1] Includes iron and steel plants, primary smelters producing alloys other than copper, consumers of copper powder and copper shot, and miscellaneous manufacturers.

Table 37.—Stocks of copper in the United States, Dec. 31

(Metric tons)

Year	Blister and materials in process of refining[1]	Refined copper				
		Primary producers	Wire rod mills	Brass mills	Other[2]	New York Commodity Exchange
1975	258,000	187,000	108,000	38,000	6,000	91,000
1976	291,000	172,000	104,000	32,000	6,000	182,000
1977	314,000	212,000	106,000	31,000	6,000	167,000
1978	283,000	153,000	63,000	28,000	7,000	168,000
1979	275,000	64,000	44,000	25,000	6,000	90,000

[1] Includes copper in transit from smelters in the United States to refineries therein.

[2] Includes secondary smelters, chemical plants, foundries, and miscellaneous plants.

Table 38.—Dealers' monthly average buying price for copper scrap and consumers' alloy-ingot prices at New York in 1978[1]

(Cents per pound)

Grade	Jan.	Feb.	Mar.	Apr.	May	June	
No. 2 copper scrap	34.00	35.61	35.59	39.73	39.18	41.77	
No. 1 composition scrap (red brass)	34.00	35.61	35.59	40.05	39.50	39.64	
No. 1 composition ingot (85-5-5-5)	69.83	70.00	70.00	71.50	72.50	72.50	
	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
No. 2 copper scrap	40.50	41.89	42.50	44.70	45.40	44.75	40.47
No. 1 composition scrap	39.00	40.39	41.50	43.50	44.40	43.75	39.74
No. 1 composition ingot	72.50	72.50	72.62	75.18	77.00	77.00	72.76

[1] Data not available for 1979.

Source: Metal Statistics, 1979.

Table 39.—Average monthly quoted prices of electrolytic copper for domestic delivered, in the United States and for spot copper at London

(Cents per pound)

	1978				1979			
	Domestic delivered		London spot[1]		Domestic delivered		London spot[1]	
	Cathode	Wirebar	Cathode	Wirebar	Cathode	Wirebar	Cathode	Wirebar
January	62.89	63.63	56.23	57.17	75.47	76.57	73.83	75.24
February	62.59	63.59	54.33	55.16	88.13	89.70	87.33	88.16
March	61.66	62.41	56.04	56.84	95.34	96.72	92.40	92.94
April	64.00	64.63	57.48	58.26	97.32	98.32	95.29	95.20
May	64.12	64.77	58.31	59.05	90.40	91.23	85.91	87.34
June	65.94	66.57	59.98	60.42	87.23	88.24	82.57	85.15
July	63.40	64.08	60.31	60.63	85.77	86.77	80.06	82.25
August	66.67	67.23	64.12	64.66	90.17	91.34	86.18	89.61
September	66.94	67.63	64.43	65.40	94.55	95.85	92.04	95.01
October	69.79	70.50	67.22	68.31	97.99	99.11	92.61	94.09
November	70.62	71.19	65.58	66.64	98.54	99.71	92.63	94.76
December	71.10	71.90	68.22	69.52	105.41	106.45	97.00	100.38
Average	65.81	66.51	61.06	61.88	92.19	93.33	88.25	90.07

[1] Based on average monthly rates of exchange.

Source: Metals Week.

Table 40.—Average weighted prices of copper delivered

(Cents per pound)

Year	Domestic copper	Foreign copper
1975	64.2	56.0
1976	69.6	63.5
1977	66.8	59.3
1978	66.5	61.9
1979	93.3	90.0

Source: Metals Week.

Table 41.—U.S. exports of copper, by class and destination

Year and destination	Ore and concentrates[1 2] (copper content)		Ash and residues[1] (copper content)		Refined		Scrap		Blister and precipitates[3]	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1977	14,351	$12,654	10,781	$5,992	46,745	$70,028	34,375	$36,006	7,534	$6,062
1978:										
Africa	--	--	--	--	1	5	55	68	39	91
Belgium-Luxembourg	18	18	5,815	4,742	2,518	3,761	1,791	1,775	962	1,141
Brazil	--	--	--	--	3,307	4,622	490	209	--	--
Canada	1,380	1,074	726	751	5,079	6,997	9,981	10,283	1,189	1,733
China:										
Mainland	--	--	--	--	2,991	4,370	--	--	--	--
Taiwan	--	--	11	87	901	1,421	987	910	34	84
Denmark	--	--	--	--	301	477	--	--	--	--
Finland	--	--	--	--	50	66	--	--	--	--
France	100	154	--	--	6,966	10,118	22	19	119	270
Germany, Federal Republic of	110	38	917	459	18,063	23,727	2,342	2,560	13	20
India	--	--	--	--	--	--	639	643	--	--
Iran	--	--	--	--	--	--	--	--	--	--
Israel	--	--	--	--	26	57	--	--	2	4
Italy	--	--	--	--	19,036	27,124	--	--	--	--
Japan	8,501	9,270	131	479	9,986	15,007	8,487	9,063	382	285
Korea, Republic of	--	--	--	--	247	326	19,425	22,876	3,935	3,229
Mexico	2,104	1,808	--	--	1,049	1,055	3,243	3,787	3	5
Netherlands	--	--	--	--	2,956	3,951	168	194	(3)	1
Oceania	15	35	56	282	5	11	--	--	--	--
Pakistan	--	--	--	--	--	--	18	17	--	--
Philippines	--	--	--	--	--	--	--	--	1	3
Saudi Arabia	--	--	2	6	20	39	--	--	23	72
Spain	(3)	1	848	221	5	11	625	384	3,102	3,932
Sweden	--	--	--	--	4,229	6,453	177	185	11	25
Switzerland	--	--	--	--	306	526	--	--	--	--
Thailand	--	--	--	--	--	--	109	185	--	--
U.S.S.R.	5,257	7,417	--	--	1	1	--	--	--	--
United Kingdom	--	--	619	631	13,831	19,953	332	872	396	634

See footnotes at end of table.

Table 41.—U.S. exports of copper, by class and destination —Continued

Year and destination	Ore and concentrates[1] [2] (copper content)		Ash and residues[1] (copper content)		Refined		Scrap		Blister and precipitates[2]	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1978 —Continued										
Venezuela	--	--	--	--	32	$86	--	--	9	$23
Other	(3)	$1	1	$4	31	23	236	$255	15	39
Total[4]	17,486	19,816	9,127	7,593	91,923	130,196	49,076	54,445	10,235	11,590
1979:										
Africa	--	--	--	--	6	8	18	26	71	161
Belgium-Luxembourg	--	--	2,905	5,568	2,496	4,037	2,600	2,937	295	1,124
Brazil	--	--	--	--	6,170	11,041	735	1,049	--	--
Brunei	--	--	--	--	--	--	--	--	--	--
Canada	284	211	696	449	4,548	7,834	12,306	15,257	551	1,153
China:										
Mainland	--	--	--	--	3,146	5,613	--	--	--	--
Taiwan	--	--	4	13	1,211	2,138	1,027	1,511	67	281
Costa Rica	--	--	--	--	--	--	--	--	--	--
Dominican Republic	--	--	--	--	--	--	--	--	--	--
France	--	--	--	--	12,525	21,624	16	18	--	--
Germany, Federal Republic of	2,103	2,925	171	636	3,529	6,493	6,693	8,901	58	100
India	--	--	--	--	30	73	2,627	3,077	--	--
Israel	--	--	(3)	1	11	30	--	--	2	9
Italy	--	--	--	--	11,369	19,388	146	165	(3)	2
Jamaica	--	--	--	--	--	--	--	--	--	--
Japan	41,508	61,729	197	861	1,983	3,491	4,189	5,508	9	16
Korea, Republic of	--	--	159	403	4,175	7,214	14,380	21,867	1,495	1,472
Mexico	670	1,290	--	--	5,948	11,453	3,319	4,535	351	347
Netherlands	--	--	110	281	6,568	11,538	599	718	(3)	4
Oceania	--	--	16	102	1	5	--	--	1	4
Panama	--	--	--	--	--	--	--	--	4	15
Philippines	--	--	--	--	--	--	--	--	--	--
Saudi Arabia	--	--	--	--	46	229	7	20	--	--
Singapore	--	--	--	--	12	17	194	115	9	28

Spain	--	--	330	268	38	90	3,636	2,871	4,547	4,597
Sweden	--	--	13	9	2,752	4,084	288	365	--	--
Switzerland	--	--	--	--	289	662	--	--	--	--
United Kingdom	--	--	613	823	6,528	11,118	680	858	46	137
Venezuela	--	--	--	--	151	241	--	--	3	17
Other	--	--	--	--	150	280	620	827	24	47
Total[4]	44,565	66,155	5,215	9,415	73,677	128,703	54,080	70,624	7,445	9,515

	Pipes and tubing		Plates and sheets		Wire and cable, bare		Wire and cable, insulated		Other copper manufactures[5]	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1977	2,794	$8,311	1,393	$3,060	5,289	$14,081	76,231	$235,785	6,278	$10,923
1978:										
Africa	171	488	3	16	224	748	11,186	29,606	39	86
Belgium-Luxembourg	25	55	26	118	74	274	382	4,019	3	9
Brazil	10	37	--	--	7	54	506	1,709	201	320
Canada	629	1,602	304	867	1,232	2,414	24,945	32,759	2,885	4,850
China:										
Mainland	8	116	--	--	--	--	2	1	--	--
Taiwan	21	78	21	140	192	725	398	2,134	--	--
Denmark	--	--	1	12	16	55	60	567	18	9
Finland	--	--	--	--	1	3	6	214	2	10
France	16	33	5	36	12	60	328	4,638	9	118
Germany, Federal Republic of	52	108	3	14	9	55	549	7,074	20	56
India	1	7	4	17	3	14	27	262	1	6
Iran	136	349	177	417	156	377	11,772	86,874	46	101
Israel	50	139	(3)	3	5	64	533	3,725	3	6
Italy	3	14	1	5	5	55	147	2,559	564	843
Japan	4	13	5	28	129	244	422	4,208	61	183
Korea, Republic of	--	--	--	--	258	328	115	2,097	1	5
Mexico	199	568	10	42	2,571	6,353	7,175	18,436	152	268
Netherlands	22	68	(3)	3	24	60	237	1,757	216	905
Oceania	9	36	1	7	69	163	398	3,219	12	55
Pakistan	2	7	1	7	32	40	79	196	--	--
Philippines	2	13	--	--	9	43	629	2,756	1	3

See footnotes at end of table.

Table 41.—U.S. exports of copper, by class and destination —Continued

	Pipes and tubing		Plates and sheets		Wire and cable, bare		Wire and cable, insulated		Other copper manufactures[5]	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1978 —Continued										
Saudi Arabia	434	$1,334	12	$25	2,170	$4,751	11,701	$36,937	22	$75
Spain	(3)	5	26	72	13	20	151	1,413	--	--
Sweden	--	--	1	5	45	121	81	1,684	2	16
Switzerland	--	--	--	--	1	11	60	645	--	--
Thailand	3	8	2	13	18	23	33	214	--	--
U.S.S.R.	(3)	1	--	--	--	--	91	716	--	--
United Kingdom	37	140	6	34	44	247	1,564	8,452	141	324
Venezuela	130	478	5	27	293	964	1,246	5,829	3,470	5,170
Other	679	1,785	198	410	875	3,645	6,349	24,325	730	1,235
Total[4]	2,645	7,485	813	2,319	8,489	21,911	81,171	289,025	8,594	14,654
1979:										
Africa	188	695	5	32	284	1,334	5,372	16,305	6	19
Belgium-Luxembourg	21	69	2	9	53	270	263	1,906	3	23
Brazil	28	94	--	--	55	235	20,596	35,940	2,235	4,495
Brunei	2	14	--	--	--	--	794	2,162	--	--
Canada	642	1,874	418	1,346	925	2,984	16,249	39,333	6,415	12,693
China:										
Mainland	--	--	--	--	--	--	18	221	--	--
Taiwan	21	42	--	--	56	231	1,662	6,557	18	58
Costa Rica	50	166	--	--	19	49	13	70	382	522
Dominican Republic	1	3	3	18	12	80	254	906	114	271
France	214	643	1	7	40	143	470	8,015	356	856
Germany, Federal Republic of	2,690	7,241	73	389	11	132	1,261	11,302	277	622
India	159	245	(3)	4	8	28	56	808	5	31
Iran	(3)	9	--	--	377	811	3,550	39,711	--	--
Israel	235	614	9	26	7	62	524	3,766	26	329
Italy	16	59	8	22	13	127	171	3,643	4,063	8,378
Jamaica	4	15	--	--	21	107	582	1,569	--	--

Japan	7	51	3	29	70	341	366	5,051	120	438
Korea, Republic of	1	2	7	30	450	817	318	2,020	10	63
Mexico	879	2,090	17	53	3,485	9,119	10,425	29,910	41	169
Netherlands	305	834	(3)	2	21	218	280	2,468	362	1,588
Oceania	33	106	(3)	2	25	106	545	3,930	32	169
Panama	9	28	1	4	40	151	565	2,191	4	13
Philippines	6	22	3	5	13	83	884	3,591	1	2
Saudi Arabia	897	3,370	3	11	1,206	3,636	8,989	33,090	55	137
Singapore	4	17	(3)	3	23	128	776	3,565	9	27
Spain	1	4	--	--	1	17	136	2,684	--	--
Sweden	18	49	--	--	37	151	115	2,202	1	2
Switzerland	--	--	(3)	2	2	25	62	817	1	5
United Kingdom	1,159	4,120	46	141	123	854	1,265	11,707	237	558
Venezuela	343	1,074	8	48	155	557	1,187	4,856	4,649	8,883
Other	594	1,981	50	159	998	4,410	3,919	22,025	35	110
Total[4]	8,527	25,480	656	2,342	8,580	27,207	81,616	302,321	19,460	40,462

[1] Matte is included with ore and concentrates in 1977 and with ash and residues in 1978 due to changes in trade classifications.

[2] Precipitate copper is included with ore and concentrates in 1977 and with blister copper in 1978 due to changes in trade classifications.

[3] Less than 1/2 unit.

[4] Data may not add to totals shown because of independent rounding.

[5] Excludes copper wire cloth: 1977-2,903,787 square feet ($1,259,741), 1978-2,976,723 square feet ($1,471,626), and 1979-308,386 square feet ($1,044,000).

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Table 42.—U.S. exports of copper scrap, by country

Country	Unalloyed copper scrap				Copper alloy scrap			
	1978		1979		1978		1979	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Argentina	--	--	61	$81	--	--	1,018	$869
Belgium-Luxembourg	1,791	$1,775	2,600	2,937	4,041	$3,652	10,961	13,561
Brazil	490	209	735	1,049	1,774	956	1,624	2,253
Canada	9,981	10,398	12,306	15,257	10,943	8,945	10,553	12,571
Finland	--	--	11	12	409	470	1,425	2,273
German Democratic Republic	91	100	170	230	--	--	37	58
Germany, Federal Republic of	2,342	2,560	6,693	8,901	8,520	5,220	15,774	18,240
Hong Kong	109	108	183	259	204	255	742	840
India	639	648	2,627	3,077	5,544	5,791	11,060	12,902
Italy	--	--	146	165	588	344	862	984
Japan	8,487	9,663	4,189	5,506	22,916	24,636	18,954	23,824
Korea, Republic of	19,425	22,876	14,380	21,867	28,434	29,822	20,732	28,769
Mexico	3,243	3,787	3,319	4,535	1,041	321	1,964	1,652
Netherlands	168	194	599	718	993	1,123	1,431	1,981
Spain	625	384	3,636	2,871	11,907	5,846	11,367	8,569
Sweden	177	185	288	365	665	934	1,202	1,852
Switzerland	--	--	--	--	594	474	71	87
Taiwan	937	910	1,027	1,511	5,939	3,622	3,991	3,846
Thailand	109	135	54	70	117	128	236	261
Turkey	--	--	--	--	107	109	--	--
United Kingdom	332	372	680	858	1,620	1,646	2,505	3,457
Other	131	151	376	354	361	413	493	824
Total[1]	49,076	54,445	54,080	70,624	106,717	94,705	116,992	139,673

[1] Data may not add to totals shown because of independent rounding.

Table 43.—U.S. imports[1] of unmanufactured copper (copper content), by class and country

Year and country	Ore, concentrates		Matte		Blister		Refined		Scrap		Total[2]	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1977	38,176	$48,500	16,175	$80,109	41,898	$53,718	354,506	$476,232	18,013	$20,741	468,769	$679,300
1978:												
Australia	1,784	1,615	306	324	--	--	7,944	9,918	--	--	10,034	11,857
Belgium-Luxembourg	--	--	--	--	25	63	20,151	25,618	11	16	20,187	25,697
Bolivia	--	--	489	490	37	41	--	--	--	--	526	531
Botswana	--	--	6,202	23,972	--	--	--	--	--	--	6,202	23,972
Canada	4,520	5,407	389	197	68	102	64,553	89,264	7,807	8,669	77,337	103,639
Chile	1	2	1,721	1,168	38,104	46,768	134,092	170,373	1,898	2,113	175,816	220,424
Colombia	--	--	--	--	--	--	554	706	--	--	554	706
Dominican Republic	--	--	--	--	--	--	--	--	449	488	449	488
Egypt	--	--	--	--	--	--	997	1,254	--	--	997	1,254
Finland	--	--	--	--	--	--	2,075	2,494	--	--	2,075	2,494
France	--	--	--	--	2	3	150	197	351	762	503	962
Germany, Federal Republic of	--	--	--	--	--	--	8,444	11,093	39	77	8,483	11,170
Japan	--	--	--	--	--	--	4,205	5,270	22	18	4,227	5,288
Mauritania	--	--	--	--	1,277	518	--	--	--	--	1,277	518
Mexico	129	197	--	--	1,709	2,260	178	231	3,802	4,067	5,818	6,755
Netherlands	--	--	--	--	--	--	1,499	1,781	13	5	1,512	1,786
Norway	--	--	--	--	--	--	336	425	--	--	336	425
Peru	2,362	3,071	11	14	33,358	40,291	58,888	73,573	141	182	94,760	117,131
Philippines	11,986	16,075	--	--	--	--	--	--	--	--	11,986	16,075
South Africa, Republic of	--	--	1,606	9,533	4,104	4,678	9,768	11,169	--	--	15,478	25,380
Spain	--	--	--	--	--	--	500	608	18	30	518	638
Sweden	--	--	--	--	--	--	4,027	5,076	--	--	4,027	5,076
United Kingdom	--	--	--	--	--	--	9,435	12,374	70	117	9,505	12,491
Yugoslavia	--	--	--	--	--	--	10,889	13,631	--	--	10,889	13,631
Zaire	--	--	--	--	--	--	1,750	2,072	--	--	1,750	2,072
Zambia	--	--	--	--	--	--	74,209	90,021	5,562	6,145	79,771	96,166
Other	134	166	--	--	(3)	1	51	69	1,186	1,278	1,371	1,514
Total[2]	20,916	26,532	10,724	35,698	78,683	94,723	414,697	527,217	21,369	23,968	546,389	706,138

See footnotes at end of table.

Table 43.—U.S. imports[1] of unmanufactured copper (copper content), by class and country—Continued

Year and country	Ore, concentrates		Matte		Blister		Refined		Scrap		Total[3]	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1979:												
Australia	975	1,286	--	--	1,098	1,990	--	--	--	--	2,073	3,276
Belgium-Luxembourg	--	--	--	--	1,602	3,184	729	1,451	--	--	2,331	4,635
Bolivia	--	--	--	--	512	1,083	--	--	--	--	512	1,083
Canada	4,037	6,917	382	493	6,949	14,218	63,823	130,021	13,829	22,893	89,020	174,542
Chile	412	874	27	44	31,506	56,275	83,551	156,875	659	1,049	116,155	214,690
Dominican Republic	--	--	--	--	--	--	--	--	659	1,069	659	1,069
France	--	--	--	--	--	--	95	152	229	536	324	688
Germany, Federal Republic of	--	--	--	--	--	--	6,019	12,445	76	189	6,095	12,634
Japan	--	--	--	--	15	46	--	--	22	41	37	87
Mexico	186	240	5	5	3,185	4,761	315	655	4,807	5,346	8,498	11,007
Norway	--	--	--	--	--	--	198	378	--	--	198	378
Peru	1,491	2,157	--	--	22,039	37,672	29,298	51,748	--	--	52,828	91,577
Philippines	15,330	27,976	--	--	--	--	--	--	90	137	15,420	28,113
South Africa, Republic of	--	--	--	--	--	--	2,001	1,886	29	85	2,030	1,971
Sweden	--	--	--	--	1,231	2,561	7,494	15,096	--	--	8,725	17,657
United Kingdom	--	--	--	--	--	--	806	1,490	48	113	854	1,603
Yugoslavia	--	--	--	--	--	--	3,409	5,401	--	--	3,409	5,401
Zaire	--	--	--	--	--	--	1,471	3,000	--	--	1,471	3,000
Zambia	--	--	--	--	--	--	15,904	28,640	--	--	15,904	28,640
Other	2	4	(2)	1	(2)	1	49	82	1,730	2,277	1,781	2,365
Total[3]	22,433	39,426	414	543	68,137	121,786	215,161	408,826	22,178	33,730	328,323	604,310

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[1] Data are general imports, that is, they include copper imported for immediate consumption plus material entering the country under bond.
[2] Less than 1/2 unit.
[3] Data may not add to totals shown because of independent rounding.

Table 44.—Copper: World mine production, by country[1]

(Thousand metric tons)

Continent and country	1976	1977	1978[p]	1979[e]
North and Central America:				
Canada[2]	730.9	759.4	659.4	[3]643.8
Cuba	[r]3.0	2.6	2.9	2.5
Guatemala	2.9	2.1	2.7	2.5
Honduras	.4	.5	.6	1.0
Mexico	89.0	89.7	87.2	[3]90.0
Nicaragua[4]	[r]1.3	.5	[e].1	--
United States[2]	1,456.6	1,364.4	1,357.6	[3]1,443.6
South America:				
Argentina	.3	.2	.2	.2
Bolivia	[r]5.1	3.7	3.3	[3]1.8
Brazil	[r].1	(5)	--	5.0
Chile	[r]1,005.2	1,056.2	1,035.5	[3]1,060.6
Colombia	--	.9	[e].5	.5
Ecuador	[e].3	.7	.6	.7
Peru	220.3	341.0	366.5	[3]400.4
Europe:				
Albania[e]	10.0	10.0	11.5	13.0
Austria	1.1	--	--	--
Bulgaria	57.0	57.0	60.0	63.0
Czechoslovakia[e]	[r]5.0	[r]5.2	5.5	5.6
Finland	[r]41.7	46.7	46.9	41.1
France	.5	.3	.6	.6
German Democratic Republic[e]	16.0	17.0	16.0	16.0
Germany, Federal Republic of[2] [6]	1.6	1.2	.8	.9
Greece[6]	[r]2.6	3.5	.3	--
Hungary	[r]1.3	1.0	.5	.3
Ireland[4]	4.1	4.9	4.8	4.1
Italy[6]	[r].9	.7	.5	.5
Norway[6]	[r]31.1	29.1	28.3	[3]28.0
Poland[3]	267.0	289.3	321.0	325.0
Portugal[6]	[r]4.5	3.2	3.6	3.0
Romania[2]	[r]23.0	27.0	27.0	27.0
Spain[6] [7]	35.6	48.3	42.2	45.0
Sweden	44.9	44.8	47.6	[3]45.8
U.S.S.R.[e] [2] [6]	[r]800.0	[r]830.0	865.0	885.0
United Kingdom	.6	.4	.2	--
Yugoslavia[4]	120.1	116.2	113.3	[3]108.0
Africa:				
Algeria	[r].4	.3	.2	.5
Botswana[8]	[r]11.9	11.8	14.6	15.0
Congo (Brazzaville)[4]	.4	1.1	.8	1.0
Ethiopia[e]	.4	--	--	--
Kenya	(5)	--	--	--
Mauritania	[r]9.4	7.6	1.8	--
Morocco[4]	[r]4.9	4.8	4.7	4.6
Mozambique[e]	(5)	(5)	.1	.1
Rhodesia, Southern[e]	[r]44.0	33.0	32.0	32.0
South Africa, Republic of	196.9	208.3	209.3	[3]190.6
South-West Africa, Territory of (Namibia)	43.5	49.2	37.7	41.0
Uganda[e]	7.0	4.0	1.3	2.1
Zaire	444.4	481.6	423.8	377.0
Zambia	708.9	656.0	643.0	600.0
Asia:				
Burma[8]	.1	(5)	.1	.1
China:				
Mainland[e]	100.0	100.0	150.0	150.0
Taiwan	2.0	2.0	.8	.9
Cyprus[6]	[r]8.0	6.8	5.8	6.0
India	[r]28.8	31.2	23.0	28.5
Indonesia	69.1	61.6	59.0	57.0
Iran[e]	6.0	13.0	20.0	10.0
Israel	2.5	--	--	--
Japan[4]	81.6	81.4	73.4	[3]60.0
Korea, North[e] [2]	[r]15.0	[r]15.0	15.0	15.0
Korea, Republic of	2.3	1.7	.8	.6
Malaysia	18.2	23.0	26.4	23.6
Nepal	--	(5)	(5)	(5)
Philippines	[r]237.6	272.8	264.0	[3]297.6
Turkey	[r]29.8	33.4	31.3	24.3
Oceania:				
Australia	218.5	221.6	207.1	234.0
Papua New Guinea	175.8	182.3	198.6	[3]170.8
Total	[r]7,451.4	7,661.2	7,557.3	7,606.8

[e]Estimate. [p]Preliminary. [r]Revised.

[1] Data presented represent copper content (recoverable, where indicated) of ore mined wherever possible. If such data are not available, the figures presented are the nonduplicative total copper content of ores, concentrates, matte, metal, and/or other copper-bearing products measured at the least stage of processing for which data are available.

[2] Recoverable.

[3] Reported figure.

[4] Copper content of concentrates produced.

[5] Less than 1/2 unit.

[6] Includes copper content of cupriferous pyrite.

[7] Excludes an unreported quantity of copper in iron pyrite which may or may not be recovered.

[8] Copper content of matte produced.

[9] Revised to zero.

Table 45.—World smelter copper production[1]

(Thousand metric tons)

Continent, country, and metal origin	1976	1977	1978[p]	1979[e]
North and Central America:				
Canada:				
Primary	457.6	481.6	[e]410.3	379.0
Secondary	31.0	18.7	[e]15.0	10.0
Total	488.6	500.3	425.3	[3]389.0
Mexico, primary only	85.2	87.5	87.0	[3]93.6
United States:				
Primary	1,392.2	1,302.0	1,288.4	[3]1,335.6
Secondary	46.3	44.8	54.2	[3]60.2
Total	1,438.5	1,346.8	1,342.6	[3]1,395.8
South America:				
Argentina, primary only	.1	.1	.1	.1
Brazil, primary only	.4	--	--	--
Chile, primary only	856.2	888.4	927.4	[3]946.9
Peru, primary only	188.4	321.1	318.9	[3]371.4
Europe:				
Albania, primary only[e]	9.0	9.0	9.5	11.0
Austria:				
Primary	.9	--	--	--
Secondary	12.1	12.1	12.1	13.2
Total	13.0	12.1	12.1	13.2
Belgium-Luxembourg:				
Primary[e]	14.0	13.0	9.0	9.2
Secondary[e]	58.0	48.6	46.9	47.8
Total	72.0	61.6	55.9	57.0
Bulgaria:				
Primary[e]	57.0	57.0	60.0	62.0
Secondary[e]	3.0	3.0	3.0	3.0
Total	60.0	60.0	63.0	65.0
Czechoslovakia, primary and secondary[e]	10.0	10.0	10.0	10.0
Finland:				
Primary	51.5	61.5	53.7	46.7
Secondary	[e]9.5	10.6	10.0	9.2
Total	61.0	72.1	63.7	55.9
France, secondary only	2.2	5.3	3.2	7.0
German Democratic Republic, primary only	16.0	18.0	17.0	17.0
Germany, Federal Republic of:				
Primary	193.7	189.6	165.8	227.9
Secondary	50.8	58.4	55.7	60.4
Total	244.5	248.0	221.5	288.3
Hungary:				
Primary	1.1	.8	.3	.1
Secondary	4.1	3.0	--	--
Total	5.2	3.8	.3	.1
Norway, primary only	23.4	26.6	20.1	[3]27.4
Poland, primary and secondary	281.2	311.0	337.0	341.0
Portugal:				
Primary	2.8	3.3	2.8	3.0
Secondary	.1	.1	.2	.4
Total	2.9	3.4	3.0	3.4
Romania:				
Primary	40.5	41.4	38.9	39.0
Secondary	5.0	4.0	4.0	4.0
Total	45.5	45.4	42.9	43.0
Spain:				
Primary	92.5	99.5	95.5	96.0
Secondary	20.0	18.0	17.0	18.0
Total	112.5	117.5	112.5	114.0

See footnotes at end of table.

Table 45.—World smelter copper production[1] —Continued

(Thousand metric tons)

Continent, country, and metal origin	1976	1977	1978[p]	1979[e]
Europe: —Continued				
Sweden:				
Primary	46.5	46.7	53.2	[3]51.6
Secondary	15.5	15.0	13.8	[3]12.9
Total	62.0	61.7	67.0	[3]64.5
U.S.S.R.:				
Primary	840.0	850.0	865.0	885.0
Secondary	80.0	85.0	90.0	95.0
Total	920.0	935.0	955.0	980.0
Yugoslavia:				
Primary	[e]99.0	97.4	100.0	100.0
Secondary	[e]65.1	68.4	65.0	52.0
Total	164.1	165.8	165.0	[3]152.0
Africa:				
Rhodesia, Southern, primary only	23.5	28.0	26.2	26.0
South Africa, Republic of, primary only	168.0	188.4	189.4	[3]176.4
South-West Africa, Territory of (Namibia), primary only	36.1	36.2	37.7	41.0
Uganda, primary only	7.0	[e]4.0	[e]1.3	1.3
Zaire, primary only	413.0	443.0	390.7	343.8
Zambia, primary only	711.7	658.8	654.0	620.0
Asia:				
China:				
Mainland, primary and secondary[e]	100.0	100.0	150.0	150.0
Taiwan, primary only	11.7	11.5	13.0	14.0
India, primary only	24.8	23.5	19.6	24.1
Iran, primary only	4.0	7.0	6.0	6.0
Japan:				
Primary	769.4	848.4	854.5	861.4
Secondary	89.4	103.9	56.0	60.0
Total	858.8	952.3	910.5	[3]921.4
Korea, North:				
Primary	15.0	15.0	15.0	15.0
Secondary	5.0	5.0	5.0	5.0
Total	20.0	20.0	20.0	20.0
Korea, Republic of:				
Primary	13.6	19.2	17.3	20.0
Secondary	17.3	23.7	35.1	43.1
Total	30.9	42.9	52.4	[3]63.1
Turkey:				
Primary[e]	27.1	30.9	25.6	21.6
Secondary[e]	.6	.6	.6	.6
Total	27.7	31.5	26.2	[3]22.2
Oceania: Australia:				
Primary	167.3	167.7	164.4	156.7
Secondary	3.0	4.1	2.7	3.0
Total	170.3	171.8	167.1	[3]159.7
Grand total	7,769.5	8,029.4	7,924.1	8,035.6
Of which:				
Primary	6,860.3	7,076.1	6,937.6	7,029.8
Secondary	518.0	582.3	489.5	504.8
Undifferentiated	391.2	421.0	497.0	501.0

[e] Estimate. [p] Preliminary.

[1] This table has been revised in general format to include total production of copper metal at the unrefined stage, whether produced by thermal, electrolytic, or electrowinning methods, and whether derived from ores, concentrates, or matte (primary) and/or scrap (secondary). To the extent possible, primary and secondary output of each country is shown separately. In some cases, total smelter production is officially reported, but the distribution between primary and secondary has been estimated. In instances where copper is recovered in a single step from raw material to refined product, the amount recovered has been included.

[3] Reported figure.

Table 46.—Copper: World refinery production[1]

(Thousand metric tons)

Continent, country, and metal origin	1976	1977	1978[p]	1979[e]
North and Central America:				
Canada:				
Primary[e]	479.5	479.8	420.3	377.3
Secondary[e]	31.0	29.0	26.0	20.0
Total	510.5	508.8	446.3	[2]397.3
Mexico:				
Primary[e]	67.4	67.1	70.0	84.7
Secondary[e]	8.0	6.0	5.0	6.1
Total	75.4	73.1	75.0	90.8
United States:				
Primary	1,396.4	1,357.3	1,449.1	[2]1,515.4
Secondary	340.3	349.6	420.1	[2]498.4
Total	1,736.7	1,706.9	1,869.2	[2]2,013.8
South America:				
Argentina, primary only	1.5	--	--	--
Brazil, secondary only	51.8	49.1	43.2	50.1
Chile, primary only	632.0	676.0	749.1	[2]779.1
Peru, primary only	135.6	188.1	182.8	[2]230.8
Europe:				
Albania, primary only[e]	7.0	7.0	7.0	8.0
Austria:				
Primary[e]	8.6	9.7	15.5	16.3
Secondary[e]	20.0	22.0	16.0	16.5
Total	28.6	31.7	31.5	[2]32.8
Belgium-Luxembourg:				
Primary[e]	359.0	408.7	332.6	330.0
Secondary[e]	66.0	56.0	56.0	56.0
Total	425.0	464.7	388.6	386.0
Bulgaria, primary and secondary[e]	53.0	53.0	55.0	60.0
Czechoslovakia, primary and secondary	22.1	23.1	23.8	24.5
Finland:				
Primary[e]	34.1	32.8	32.7	33.0
Secondary[e]	4.0	10.0	10.0	10.0
Total	38.1	42.8	42.7	[2]43.0
France:				
Primary	19.3	22.3	20.7	22.0
Secondary	20.0	22.7	21.3	23.4
Total	39.3	45.0	42.0	[2]45.4
German Democratic Republic, primary and secondary[e]	50.0	51.0	49.0	49.0
Germany, Federal Republic of:				
Primary[e]	285.6	276.2	245.4	228.5
Secondary[e]	161.0	164.0	158.0	148.0
Total	446.6	440.2	403.4	[2]376.5
Hungary, primary and secondary	10.6	11.9	13.1	13.2
Italy:				
Primary[e]	4.8	4.0	3.5	3.0
Secondary[e]	22.0	16.0	14.0	15.0
Total	26.8	20.0	17.5	18.0
Norway:				
Primary	17.8	20.0	14.5	[2]21.0
Secondary	6.2	[e]6.6	[e]5.6	6.0
Total	24.0	26.6	20.1	27.0
Poland, primary and secondary	270.1	306.6	332.2	335.8
Portugal, primary only	2.8	3.4	3.0	[2]3.4
Romania, primary and secondary	[e]38.0	40.0	40.5	40.5
Spain:				
Primary[e]	110.9	130.0	117.0	119.4
Secondary[e]	31.0	29.0	30.0	25.0
Total	141.9	159.0	147.0	[2]144.4

See footnotes at end of table.

Table 46.—Copper: World refinery production[1] —Continued

(Thousand metric tons)

Continent, country, and metal origin	1976	1977	1978[p]	1979[e]
Europe: —Continued				
Sweden:				
Primary	55.6	47.7	53.2	49.7
Secondary	7.3	14.0	13.8	11.0
Total	62.9	61.7	67.0	[2]60.7
U.S.S.R.:				
Primary[e]	760.0	790.0	810.0	830.0
Secondary[e]	160.0	160.0	170.0	170.0
Total	920.0	950.0	980.0	1,000.0
United Kingdom:				
Primary	51.5	44.4	46.2	[2]48.5
Secondary	85.7	77.8	79.4	[2]73.2
Total	137.2	122.2	125.6	[2]121.7
Yugoslavia:				
Primary	121.6	93.0	[e]97.4	92.5
Secondary	14.9	50.5	[e]53.4	45.0
Total	136.5	143.5	150.8	[2]137.5
Africa:				
Rhodesia, Southern, primary only[e] [3]	23.5	28.2	26.2	27.5
South Africa, Republic of, primary only[2]	95.6	145.9	152.5	[2]150.8
Zaire, primary only	66.0	98.7	102.8	98.7
Zambia, primary only	694.2	648.0	627.7	600.0
Asia:				
China:				
Mainland, primary and secondary[e]	150.0	150.0	200.0	200.0
Taiwan, secondary only	11.7	11.5	14.5	13.7
India, primary only[2]	20.9	22.8	17.6	30.3
Iran, primary only[e]	7.0	7.0	6.0	6.0
Japan:				
Primary	769.8	848.4	854.5	850.3
Secondary	94.6	85.3	104.6	133.4
Total	864.4	933.7	959.1	[2]983.7
Korea, North, primary and secondary	25.0	25.0	25.0	25.0
Korea, Republic of:				
Primary	30.9	42.9	52.4	52.1
Secondary	[e]10.0	[e]10.0	13.0	11.0
Total	40.9	52.9	65.4	63.1
Turkey, primary only	28.3	25.3	30.1	[2]22.2
Oceania: Australia:				
Primary	160.3	152.0	152.6	138.2
Secondary	28.0	31.1	21.9	34.8
Total	188.3	183.1	174.5	173.0
Grand total	8,239.8	8,537.5	8,706.8	8,883.3
Of which:				
Primary	6,447.5	6,676.7	6,692.4	6,768.7
Secondary	1,173.5	1,200.2	1,275.8	1,366.5
Undifferentiated	618.8	660.6	738.6	748.0

[e] Estimate. [p] Preliminary.

[1] This table has been revised in general format to include total production of refined copper, whether produced by thermal, electrolytic, or electrowinning methods, and whether derived from primary unrefined copper or from scrap. To the extent possible, primary and secondary output of each country is shown separately. In some cases, total smelter production is officially reported, but the distribution between primary and secondary has been estimated.

[2] Reported figure.

[3] Although only primary production is reported, a small but unknown additional output of secondary refined copper may have been produced.

Table 46.—Copper: World refinery production, by country—Continued

(Thousand metric tons)

Portugal, primary and secondary	[illegible]	[illegible]	[illegible]	[illegible]
Portugal, primary only	[illegible]	[illegible]	[illegible]	[illegible]
Romania, primary and secondary	[illegible]	[illegible]	[illegible]	[illegible]
Spain:				
Primary	[illegible]	[illegible]	[illegible]	[illegible]
Secondary	[illegible]	[illegible]	[illegible]	[illegible]
Total	[illegible]	[illegible]	[illegible]	[illegible]

See footnotes at end of table.

Diatomite

By A. C. Meisinger[1]

The U.S. diatomite industry achieved a record output of processed diatomite in 1979 that totaled 717,000 tons in quantity and $90.3 million in value. This compares with production of 651,000 tons valued at $72.4 million in 1978. Production came from four Western States. California operations accounted for 59% of the U.S. total quantity sold and used in 1979 and 58% in 1978.

The primary domestic use of diatomite was as a filter aid material (accounting for 65% of U.S. consumption in 1979 and 63% in 1978). Other uses, in order of quantity sold and used, were for fillers, absorbents, and insulation.

Continuing cost increases for fuel, transportation, labor, and packaging materials increased the average 1979 unit price for processed diatomite by 13% over that of 1978.

U.S. diatomite exports totaled 170,000 tons in 1979, compared to 153,000 tons in 1978. Diatomite imports increased from 200 tons in 1978 to 528 tons in 1979.

DOMESTIC PRODUCTION

U.S. production of diatomite (in terms of quantity processed) increased for the fifth straight year and totaled a record 717,000 tons in 1979, compared with the previous record production of 664,000 tons in 1974 and with 651,000 tons in 1978. Total value of 1979 sales was $90.3 million, or nearly $18 million above the 1978 record sales value of $72.4 million.

U.S. output of diatomite in 1979 come from 13 mining operations in 4 Western States: California, Nevada, Oregon, and Washington; and this output was processed in 10 plants. California diatomite operations accounted for 59% of the total quantity sold and used, compared with 58% in 1978.

Principal producers in 1979 were Johns-Manville Corp., with operations at Lompoc, Calif.; Grefco, Inc. (Dicalite Div.) at Lompoc, Calif. and Mina (Basalt), Nev.; Eagle-Picher Industries, Inc. (Minerals Div.) at Sparks and Lovelock, Nev.; and Witco Chemical Corp. (Inorganic Specialties Div.) at Quincy, Wash. Production during the year also came from operations of Airox Earth Resources, Inc., and Excel-Mineral Co. in California; Cyprus Industrial Minerals Co. of Cyprus Mines Corp. in Nevada; and Oil-Dri West Production Co. in Oregon.

Pilot plant studies that began in 1978 to develop commercial uses for diatomite were continued by the American Exploration and Management Company on samples from a deposit in Rio Arriba County, N. Mex.

The Christmas Valley, (Lake County), Oreg., diatomite operations of the American Fossil Co., Inc., were acquired by Oil-Dri Corp. of America in 1978, and Cyprus Mines Corp. (a producer of diatomite in Nevada) became part of Standard Oil Co. of Indiana in late 1979.

Table 1.—Diatomite sold or used by producers in the United States

(Thousand short tons and thousand dollars)

	1975	1976	1977	1978	1979
Domestic production (sales)	578	681	648	651	717
Total value of sales	45,812	54,981	63,870	72,429	90,323

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CONSUMPTION AND USES

For the fourth straight year, the quantity of diatomite used as a filter medium (463,000 tons) increased in 1979, accounting for 65% of total U.S. consumption compared with 63% in 1978. The combined use of diatomite in fillers, absorbents, insulation, and pozzolan totaled nearly 233,000 tons in 1979, or 32% of U.S. consumption, compared with 216,000 tons, or 33% in 1978. The remaining 3% of U.S. diatomite consumption was for abrasives, coatings, catalysts, admixtures, and silicates.

Table 2.—Domestic consumption of diatomite, by principal use

(Percent of total consumption)

Use	1975	1976	1977	1978	1979
Filtration	60	60	59	63	65
Fillers	W	W	W	23	21
Insulation	4	5	5	3	3
Other	36	35	36	11	11

W Withheld to avoid disclosing company proprietary data; included with "Other".

PRICES

The weighted average value for processed diatomite sold by producers in 1979 was $125.91 per ton, compared with $111.23 per ton in 1978. Values for all major diatomite end uses in 1979 increased over those in 1978 (table 3). Continued cost increases for fuel, transportation, labor, and packaging materials were generally responsible for the price increases of diatomite products, which resulted in an annual average value increase of 13% over that of 1978.

Table 3.—Average annual value per ton[1] of diatomite, by use

Use	1977	1978	1979
Abrasives	$156.07	$172.26	$174.09
Fillers	106.62	102.51	118.22
Filtration	109.79	122.18	136.52
Insulation	70.08	81.68	94.67
Miscellaneous[2]	[r]63.65	76.07	87.81
Weighted average	98.56	111.23	125.91

[r] Revised.

[1] Based on unrounded data.

[2] Includes absorbents, admixtures and silicates, catalysts (1979), fertilizer coatings, inert carriers (1977), light weight aggregates (1977-78), and pozzolan additive.

FOREIGN TRADE

The quantity and value of processed diatomite exported in 1979 was up significantly over that of 1978 (table 4). In 1979, 58% (compared to 60% in 1978) of U.S. diatomite exports went to the following five countries: Canada, 29,300 tons; Japan, 21,600 tons; the Federal Republic of Germany, 19,600 tons; the United Kingdom, 14,800 tons; and Australia, 13,500 tons. The total quantity exported in 1979 (170,000 tons) represented 23.7% of U.S. production, compared to 23.5% in 1978.

Imports of diatomite totaled 528 tons in 1979, compared with 200 tons 1978. The quantity imported from Mexico (99% of all imports) in 1979 was 524 tons valued at $83,314, or $159 dollars per ton (U.S. Customs declared average value at U.S. ports of entry). Mexico was also the principal source of imports (72%) in 1978.

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[1] Industry economist, Section of Nonmetallic Minerals.

Table 4.—U.S. exports of diatomite

(Thousand short tons and thousand dollars)

Year	Quantity	Value[1]
1976	149	16,982
1977	152	18,876
1978	153	21,463
1979	170	26,496

[1]U.S. Customs.

Table 5.—Diatomite: World production by country

(Short tons)

Country	1976	1977	1978[p]	1979[e]
North America:				
Canada[e]	550	550	550	550
Costa Rica	790	750	672	700
Mexico	28,984	25,986	24,749	25,000
United States	631,380	648,043	651,000	717,000
South America:				
Argentina	15,267	[r]13,599	11,928	11,300
Brazil (marketable)	[r]5,551	[r]12,350	36,310	37,000
Chile	364	529	5,520	5,500
Colombia	[r]717	694	[e]700	700
Peru	[e]19,800	20,723	18,200	18,000
Europe:				
Austria	2,075	267	591	600
Denmark:				
Diatomite[e]	28,000	28,000	28,000	28,000
Meler[e]	250,000	250,000	250,000	200,000
France	231,766	[e]220,000	[e]220,000	220,000
Germany, Federal Republic of	58,365	54,517	47,800	45,000
Iceland[1]	25,021	23,132	22,068	22,000
Italy[e]	[r]33,000	[e]33,000	NA	NA
Portugal	[r]3,472	3,737	2,976	3,000
Romania[e]	45,000	45,000	45,000	45,000
Spain	[r][e]18,900	[r]31,174	[e]31,000	31,000
Sweden	360	--	--	--
U.S.S.R.[e]	[r]300,000	[r]300,000	300,000	300,000
United Kingdom	[e]3,900	2,205	[e]2,200	2,200
Africa:				
Algeria	4,763	4,520	4,437	4,400
Egypt	360	411	109	100
Kenya	2,941	2,691	1,870	1,800
South Africa, Republic of	682	734	1,025	1,000
Asia:				
Korea, Republic of	14,862	25,331	20,773	21,000
Thailand	--	209	1,218	1,200
Turkey	9,400	9,911	[e]9,900	10,000
Oceania:				
Australia	[r]1,631	[r]1,419	459	500
New Zealand	[e]3,300	1,227	1,100	1,100
Total	[r]1,736,000	[r]1,761,000	1,740,000	1,750,000

[e]Estimate. [p]Preliminary. [r]Revised. NA Not available.
[1]Exports.

[illegible]

[illegible]

The [illegible] in 1972 [illegible] Federal Republic of Germany, [illegible] the United Kingdom, 11,800 [illegible] tons, 15,500 tons. The [illegible]

[illegible] dollars per ton [illegible] 1976.

[illegible]

Feldspar, Nepheline Syenite, and Aplite

By Michael J. Potter[1]

Feldspar was mined in 10 States in 1978, with North Carolina in the lead followed by Connecticut and Georgia. Other major producing States were California, Oklahoma, and South Dakota. In 1979, only seven States were producers, with Arizona, Colorado, and Maine no longer included. Shipments in both years went to at least 31 States and to foreign destinations such as Canada and Mexico. Aplite of glassmaking quality was produced only in Virginia; output figures are not released, but output increased in 1978 and decreased slightly in 1979. Imports of nepheline syenite increased in 1978, but showed a decrease in 1979.

The 1978 end use distribution of total feldspar in the United States indicated 54% going into glassmaking and 39% into pottery. The remaining 7% was used in other applications such as enamels, soaps, sanitary ware, etc. The 1979 end use distribution of total U.S. feldspar was 55% in glass, 42% in pottery, and 3% in miscellaneous.

As a replacement for its old deposit, the Feldspar Corp. was planning to develop a new potash feldspar deposit for its Monticello, Ga., flotation plant. Further process development work was planned, to coincide with property development scheduled for 1979. In Maine, output of potash feldspar ceased from the mill at West Paris. In Arizona, the potash feldspar operation at Kingman shut down in the latter part of 1978.

In other 1978 developments, the Glass Containers Corp., Div. of Owens-Illinois, Inc., put into operation its most automated plant at Volney, N. Y. Fuel oil and propane are used instead of natural gas.[2] In Dayville, Conn., the Glass Containers Corp. was using recycled glass (cullet) as a means of reducing particulate emissions into the air and using less fuel.[3]

Legislation and Government Programs.— According to provisions of the Tax Reform Act of 1969, which continued in force throughout 1978-79, the depletion rate allowed on feldspar production (both domestic and foreign operations) was 14%.

Table 1.—Salient feldspar and nepheline syenite statistics

		1975	1976	1977	1978	1979
United States:						
Feldspar produced[1]	short tons	[2]669,900	[2]739,700	[2]734,000	735,000	740,000
Value	thousands	[2]$11,730	[2] [3]$17,530	[2] [3]$17,190	[2] [3]$18,200	[2] [3]$21,500
Exports	short tons	[2]9,540	[2]6,140	[2]6,200	10,330	12,300
Value	thousands	$507	$352	$394	$853	$1,025
Imports for consumption	short tons	290	93	242	39	266
Value	thousands	$23	$18	$8	$3	$31
Imports for consumption, nepheline syenite	short tons	431,100	501,200	502,600	548,000	536,000
Value	thousands	$6,967	$8,823	$9,135	$10,446	$10,846
Consumption, apparent[4] (feldspar plus nepheline syenite)	thousand short tons	1,092	1,235	1,231	1,273	1,264
World production (feldspar)	do	2,995	[r]3,094	[r]3,239	3,402	3,412

[r] Revised.

[1] Includes hand-cobbed feldspar, flotation-concentrate feldspar, and feldspar in feldspar-silica mixtures; also includes potash feldspar (8% K_2O or higher).

[2] Revised to rounded figure.

[3] Data represent a more refined product and are not comparable to previous years.

[4] Measured by quantity produced plus imports, minus exports (rounded figures).

FELDSPAR

DOMESTIC PRODUCTION

Soda feldspar is defined commercially as containing 7% Na_2O or higher, while potash feldspar contains 10% K_2O or higher. Hand-cobbed or hand-sorted feldspar is usually obtained from pegmatites (coarse-grained, igneous dike rock) and is relatively high in K_2O compared with Na_2O. Feldspar flotation concentrates can be classified as either soda, potash, or "mixed" feldspar, depending on the relative amounts of Na_2O and K_2O present. Feldspar-silica mixtures (feldspathic sand) can either be a naturally occurring material, such as sand deposits, or a processed mixture obtained from flotation.

The data for potash feldspar in tables 1-6 were collected from the three U.S. producers of this material; and some of this feldspar contained less than 10% K_2O (8% to 10% K_2O). Therefore, in order that potash feldspar data could be published, and maintain company data proprietary, the data in tables 1-6 are for a K_2O content of 8% or higher.

Feldspar was mined in 10 States in 1978, with North Carolina in the lead, followed in descending order by Connecticut, Georgia, California, Oklahoma, South Dakota, Arizona, Wyoming, Colorado, and Maine. The combined output of the first four States named amounted to 93% of the U.S. total. In 1979, feldspar output came from seven States, with Arizona, Colorado, and Maine no longer listed as producers. The combined output of the first four States, North Carolina, Connecticut, Georgia, and Oklahoma, amounted to 94% of the U.S. total.

Most of the feldspar used in glassmaking is ground no finer than 20 mesh, and substantial tonnages of feldspathic sands (feldspar-quartz mixtures) enter into glass furnace feeds with no further reduction in particle size. Feldspar to be used in ceramic and filler applications is usually pulverized to minus 200-mesh or finer. In 1978, 14 U.S. companies operating 16 plants produced feldspar in 10 States for shipment to destinations in at least 31 States and foreign destinations such as Canada and Mexico. North Carolina had five plants, California had two, and the other producing States had one plant each: Arizona, Colorado, Connecticut, Georgia, Maine, Oklahoma, South Dakota, and Wyoming. In 1979, 11 U.S. companies operating 13 plants produced feldspar in 7 States for shipment to destinations in at least 31 States and foreign destinations such as Canada and Mexico.

The Feldspar Corp. was involved in the development of a new ore source for its Monticello, Ga., plant to extend the useful life of the facility. The company plans to conduct further process studies and obtain additional permits in the development of the potash feldspar deposit. Output of feldspar ceased in 1978 from the mill at West Paris, Maine. The new owner of the mill planned to initially produce garnet. In Arizona, the feldspar operation at Kingman shut down in the latter part of 1978.

Table 2.—Feldspar produced in the United States[1]

(Thousand short tons and thousand dollars)

Year	Hand-cobbed		Flotation concentrate		Feldspar-silica mixtures[2]		Total[3]	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1975	17	274	531	9,260	122	[4]2,190	670	[4]11,700
1976[5]	28	321	601	[4]13,610	111	[4]3,600	740	[4]17,500
1977[5]	23	309	568	[4]12,600	142	[4]4,280	734	[4]17,200
1978[5]	26	400	568	13,240	140	4,550	735	18,200
1979[5]	20	238	580	16,460	140	4,770	740	21,500

[1] Includes potash feldspar (8% K_2O or higher).

[2] Feldspar content.

[3] Data may not add to totals shown because of independent rounding.

[4] Revised to rounded figure.

[5] Value data represent a more refined product and are not comparable to those of previous years.

CONSUMPTION AND USES

In 1978-79, there continued to be no significant consumption of run-of-mine feldspar. The majority of users acquired their supplies already ground and sized by the feldspar producers, although some manufacturers of pottery, soaps, and enamels continued to purchase feldspar for grinding to their preferred specifications in their own mills. It should be noted that a substantial portion of the material classified as feldspar-silica mixtures serves in glassmaking without additional processing.

The 1978 end use distribution of total feldspar in the United States indicated that 54% of the total was consumed in glassmaking (including container glass, flat glass, and fiber glass) and 39% was used in pottery. The remaining 7% was used in a diversity of applications, including glazes, enamels, soaps, abrasives, sanitary ware, rubber products, and electrical insulators. The 1979 end use distribution of total U.S. feldspar was 55% in glass, 42% in pottery, and 3% in miscellaneous.

Potash feldspar data appear in tables 5-6 and are based on a K_2O content of 8% or higher.

Table 3.—Feldspar sold or used by producers in the United States, by use[1]

(Thousand short tons and thousand dollars)

Use	1978		1979	
	Quantity	Value	Quantity	Value
Hand-cobbed:				
Pottery	W	W	W	W
Other	26	1,260	20	1,260
Total	26	1,260	20	1,260
Flotation concentrate:				
Glass	297	6,700	304	7,250
Pottery	W	W	W	W
Other	271	9,390	281	10,660
Total	568	16,090	585	17,910
Feldspar-silica mixture:[2]				
Glass	100	3,500	102	3,590
Pottery	W	W	W	W
Other	41	1,900	38	1,840
Total	141	5,400	140	5,430
Total:				
Glass[3]	397	10,200	406	10,840
Pottery	284	9,925	312	12,220
Other[4]	54	2,625	27	1,540
Total	735	22,750	[5]744	24,600

W Withheld to avoid disclosing company proprietary data; included with "Other."

[1] Includes potash feldspar (8% K_2O or higher).

[2] Feldspar content.

[3] Includes container glass, flat glass, and fiber glass.

[4] Includes soaps, abrasives, sanitary ware, filler, electrical insulators, etc., and unknown; totals for "Quantity" and "Value" do not correspond to the sums of the subtotals of the three "Other" categories above.

[5] Data do not add to total shown because of independent rounding.

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Table 4.—Destination of shipments of feldspar sold or used by producers in the United States, by State[1]

(Short tons)

State	1977	1978	1979
Alabama	(2)	35,500	13,900
Arkansas	5,500	5,200	W
California	(2)	(2)	[e]15,000
Connecticut	(2)	23,800	21,600
Florida	(2)	20,000	23,600
Georgia	(2)	35,800	69,000
Illinois	37,000	47,000	43,700
Indiana	30,300	32,600	25,300
Kentucky	10,100	10,200	18,100
Louisiana	16,200	19,200	16,900
Maryland	5,000	6,500	7,600
Massachusetts	18,400	W	W
Michigan	800	2,800	4,000
Mississippi	20,300	22,000	17,600
Missouri	7,600	4,200	7,000
New Jersey	45,100	50,400	59,600
New York	20,600	21,400	22,000
Ohio	63,300	59,200	64,400
Oklahoma	34,300	33,600	31,700
Pennsylvania	53,700	55,400	52,900
South Carolina	NA	W	17,700
Tennessee	21,700	19,700	19,400
Texas	39,400	38,800	40,400
West Virginia	37,000	38,200	59,800
Other[3]	267,200	153,200	97,200
Total	[4] [5]735,000	735,000	744,000

[e] Estimate. (Data are incomplete; Bureau of Mines estimate is 15,000 tons or more.) NA Not available. W Withheld to avoid disclosing company proprietary data; included with "Other."

[1] Includes potash feldspar (8% K_2O or higher).

[2] Data are incomplete; included with "Other."

[3] Includes Kansas, Rhode Island, other States, States indicated by symbol W or footnote 2, exports to foreign destinations, and unknown.

[4] Data do not add to total shown because of independent rounding.

[5] Revised to rounded figure.

Table 5.—Potash feldspar sold or used by producers in the United States, by use[1]

Use	1977		1978		1979	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Pottery	60,000	$2,384	73,500	$3,158	77,500	$4,079
Other[2]	30,700	1,125	17,800	551	16,600	592
Total	90,700	3,509	91,300	3,709	94,100	4,671

[1] K_2O content of 8% or higher.

[2] Includes glass, enamel, electrical insulators, soap, and abrasives, etc.

Table 6.—Destination of shipments of potash feldspar sold or used by producers in the United States, by State[1]

(Short tons)

State	1977	1978	1979
Illinois, Indiana, Wisconsin	W	14,900	15,500
Maryland, New York, West Virginia	27,300	27,500	29,500
Massachusetts	1,100	W	1,400
Ohio	12,100	12,100	12,000
Pennsylvania	11,100	12,000	9,000
Texas	600	400	W
Other States	34,600	18,300	18,600
Mexico	W	1,500	2,900
Canada	3,800	4,600	5,200
Other destinations	100	--	--
Total	90,700	91,300	94,100

W Withheld to avoid disclosing company proprietary data; included with "Other States."

[1] K_2O content of 8% or higher.

PRICES

Engineering and Mining Journal, December 1978 and December 1979, listed the following prices for feldspar, per short ton, f.o.b. mine or mill, carload lots, bulk, depending on grade:

	1978	1979
North Carolina:		
20 mesh, flotation	$21.75	$23.50
40 mesh, flotation	30.50	41.00
200 mesh, flotation	$32.75- 44.00	52.80
Georgia:		
40 mesh, granular	29.00- 30.50	41.00
200 mesh	39.50- 43.30	51.80
Connecticut:		
20 mesh, granular	24.00	29.00
200 mesh	32.00	41.75

Feldspar prices were quoted by Industrial Minerals (London), December 1978 and December 1979, as follows (converted from pounds sterling per metric ton to dollars per short ton, using an exchange rate of £1.00=US$2.20):

	1978	1979
Ceramic grade, powder, 200 mesh, bagged, ex-store, United Kingdom	$108-$112	$130-$140
Sand, 2 to 3 millimeters, ceramic and/or glass grade, c.i.f. main European port	55- 69	68- 84

FOREIGN TRADE

In 1978, U.S. exports classified as feldspar, leucite, and nepheline syenite (but presumably all or mostly feldspar) amounted to 10,330 tons valued at $853,161. This was two-thirds greater in tonnage than in 1977 and twice as much in value. Chief recipients of the exported material were Canada, 54%; Mexico, 14%; and Taiwan, 13%. The remaining 19% was shared among 13 other countries.

In 1979, U.S. exports classified as feldspar, leucite, and nepheline syenite (but presumably all or mostly feldspar) amounted to 12,300 tons valued at $1,024,908. Chief recipients of the exported material were Canada, 43%; Mexico, 32%; and Ecuador, 5%. The remaining 20% was shared among 10 other countries.

In addition to feldspar and nepheline syenite, U.S. imports in 1978 included 1,363 tons of material, probably feldspathic in nature, that was classified as "Other mineral fluxes, crushed" with a total value of $240,974.

U.S. imports in 1979 of "Other mineral fluxes, crushed" totaled 523 tons with a value of $146,359. Also, there were 1,121 tons of material with a value of $43,874 classified as "Other crude natural mineral fluxes."

The tariff schedule in force throughout 1978-79 for Most Favored Nations provided for a 3-1/2% ad valorem duty on ground feldspar; imports of unground feldspar were admitted duty-free.

Table 7.—U.S. imports for consumption of feldspar

(Short tons)

Country	1978		1979	
	Quantity	Value	Quantity	Value
Crude:				
Brazil	--	--	1	$1,500
Canada	39	$2,824	(1)	400
Mexico	--	--	48	4,520
Ground, crushed, or pulverized:				
Germany, Federal Republic of	(1)	411	--	--
Norway	--	--	141	13,549
Sweden	--	--	76	11,094

[1] Less than 1/2 unit.

WORLD REVIEW

Czechoslovakia.—A feldspar mine opened in the Jindrichuv Hradec district. The proven reserves at the mine of approximately 180 million tons are expected to last 70 years.[4]

France.—Feldspar imports for 1977 were 19,000 tons and came principally from the Federal Republic of Germany, 63%, and Spain, 21%. In 1976, feldspar imports amounted to almost 12,000 tons and came mainly from the Federal Republic of Germany, 71%, and Spain, 21%. Imports of nepheline syenite were 76,000 tons in 1977 and 35,000 tons in 1976 and came from Norway and Canada.[5]

Germany, Federal Republic of.—Feldspar production is given in table 6. Three other sources of feldspathic materials in the country, not included in the table, are sands (byproduct from kaolin operations), feldspar-rich rhyolites, and phonolite, which contains feldspathoids rather than feldspar. Output of pegmatite sands in 1977 was 108,000 tons and phonolite, 132,000 tons.

Feldspar imports for 1977 amounted to 53,600 tons and came principally from Norway, 47%; Italy, 24%; and France, 16%. Nepheline syenite imports were 70,000 tons, mainly from Norway.[6] Feldspar imports in 1978 were 59,900 tons, and nepheline syenite imports were 79,100 tons. Countries of origin and percents supplied were essentially the same as in 1977.[7]

United Kingdom.—Feldspar imports in 1977 totaled 146,000 tons and came principally from Norway, 51%; Finland, 24%; and Sweden, 13%. Nepheline syenite imports were 54,300 tons and came from Norway and Canada.[8] Feldspar imports in 1978 were 138,600 tons, and nepheline syenite imports were 46,500 tons. Countries of origin were generally the same as in 1977.[9]

The Dutch company, Stevin Dredging BV, carried out a reappraisal of the Durness feldspar deposit in Northern Scotland but decided not to go ahead with any exploitation. Both geological and market surveys were carried out. A 55,000-ton-per-year operation would probably have been considered viable. However, indications were that the probable size of a practical operation would only be about 9,000 to 11,000 tons per year.[10]

Table 8.—Feldspar: World production by country

(Short tons)

Country[1]	1976	1977	1978[p]	1979[e]
North America:				
Guatemala	[e]22,000	14,408	16,950	15,000
Mexico	80,732	126,005	140,604	140,000
United States	[r]739,700	734,000	735,000	[2]740,000
South America:				
Argentina	75,204	47,312	51,034	52,000
Brazil[3]	[r]104,793	118,873	118,085	129,000
Chile	[r]907	2,703	995	1,000
Colombia	38,581	29,220	29,162	30,000
Peru	[r]4,409	4,663	10,759	9,900
Uruguay	1,262	1,791	2,199	3,000
Venezuela	72,320	28,682	77,451	76,900
Europe:				
Austria	4,189	4,018	3,181	3,000
Finland	75,192	79,245	78,628	77,000
France	207,234	211,644	[e]209,000	209,000
Germany, Federal Republic of	462,944	434,082	425,040	430,000
Italy	201,287	235,446	276,771	276,000
Norway[4]	41,546	78,042	78,264	78,300
Poland[e]	33,000	[r]44,000	44,000	44,000
Portugal	14,686	16,806	18,987	29,000
Romania[e]	64,000	66,000	66,000	66,000
Spain[5]	100,271	102,760	[e]110,000	99,000
Sweden	49,324	57,504	[e]57,000	57,000
U.S.S.R.[e]	310,000	320,000	330,000	340,000
United Kingdom (china stone)[e]	55,000	55,000	55,000	55,000
Yugoslavia	27,983	61,890	[e]63,000	60,000
Africa:				
Egypt	2,346	2,902	3,678	3,690
Kenya	1,229	2,060	1,046	NA
Madagascar	--	1	[e]1	1
Mozambique[e]	940	1,000	1,000	1,000
Nigeria[e]	5,500	5,500	NA	NA
South Africa, Republic of	50,858	56,471	57,921	58,000
Zambia	[r]1,132	917	368	550
Asia:				
Burma	[r]1,884	1,567	2,205	2,000
Hong Kong	2,534	3,724	3,480	3,300
India	[r]60,965	60,307	52,672	50,000
Japan[6]	45,434	46,741	[e]46,000	45,000
Korea, Republic of	28,869	54,425	76,280	75,000
Pakistan	[r]2,982	4,077	15,769	13,000
Philippines	16,799	16,615	18,966	20,000
Sri Lanka	3,526	4,055	3,483	3,500
Thailand	13,511	19,422	35,917	35,000
Turkey	63,714	82,894	83,004	80,000
Oceania: Australia	[r]4,981	2,069	3,053	2,000
Total	[r]3,093,788	3,238,841	3,401,953	[7]3,410,000

[e]Estimate. [p]Preliminary. [r]Revised. NA Not available.

[1] In addition to the countries listed, mainland China, Czechoslovakia, Romania, and the Territory of South-West Africa (Namibia) produce feldspar, but output is not officially reported and available general information is inadequate for the formulation of reliable estimates of output levels.

[2] Reported figure.

[3] Represent sum of: (1) run-of-mine production for direct sale and (2) salable beneficiated product; total run-of-mine production was as follows in short tons: 1976—92,742; 1977—106,028; 1978—110,000; 1979—(estimate) 110,000.

[4] Described in source as lump feldspar; does not include nepheline syenite as follows in short tons: 1976—238,768; 1977—231,142; 1978—256,035; 1979, not available.

[5] Includes pegmatite.

[6] In addition, the following quantities of aplite were produced in short tons: 1976—394,533; 1977—435,015; 1978—421,000; 1979, not available.

[7] Data do not add to total shown because of independent rounding.

TECHNOLOGY

A patent was granted for sizing and desliming several hydraulically mined minerals including feldspar.[11] Ore matrix at the mining site is subjected to water under high pressure to form a slurry. The slurry goes through sizing, dewatering, and desliming operations and is then sent to a beneficiation plant for final processing.

The geology, mining, processing techniques, and marketing of several important nonmetallic minerals, including feldspar, in North Carolina were discussed; also, descriptive information about the producing companies was given.[12]

Work on recovery of North Carolina minerals has been carried out by the Minerals

Research Laboratory of North Carolina State University in Asheville. Flowsheets for feldspar, spodumene, and mica producing companies and for large phosphate and glass sand flotation plants have been developed and tested. Examples and problems of pegmatite flotation are demonstrated in a publication.[13]

Froth flotation has been extensively investigated by the Federal Bureau of Mines as a step in the multistage processing of urban refuse to recover glass suitable for use in making new containers.[14]

NEPHELINE SYENITE

Nepheline syenite is a light-colored rock that, although resembling medium-grained granite in texture, contains a significantly smaller proportion of quartz and consists principally of nepheline and alkali feldspars, usually in association with minor amounts of other minerals. Large quantities of nepheline syenite (after processing to remove contaminants, especially iron-bearing minerals) are consumed in making glass and ceramics. There is no domestic production of nepheline syenite in grades suitable for these purposes, and U.S. needs are wholly supplied by imports.

In Canada, two firms mine nepheline syenite from the deposit at Blue Mountain, Ontario: Indusmin, Ltd., and International Minerals & Chemical Corp. (Canada) Ltd. (IMC). Canadian production in 1978, the last year for which an estimate is available, totaled approximately 638,000 tons valued at $13.1 million. This represented a 1% increase in tonnage and a 9% increase in value compared with that of 1977.

In 1979, IMC announced a $5 million project to modernize and expand its crushing capacity and existing mill circuitry. Completion of the work was scheduled for late 1980, with production capacity expected to increase about 50%.[15] Indusmin, Ltd., planned to spend $1.3 million in 1979 on an expansion (removing a bottleneck at the tertiary crushing and primary milling stages of the operation).[16]

A journal article discussed the deposit at Blue Mountain, Ontario, including the two producers, processing, markets, and market areas.[17]

Other than Canada, only two countries are known to produce significant quantities of nepheline syenite—Norway with 256,000 tons in 1978, and the U.S.S.R. where, although production figures are not released, the mineral is known to serve the customary applications of the glass and ceramics industries and also as a major source of cell-feed alumina for electrolytic aluminum plants.

The price range quoted for imported nepheline syenite in Ceramic Industry magazine, January 1979, was from $14.60 to $120 per ton, and January 1980, from $16 to $110 per ton, depending upon grade, purity, grind, packaging, transportation, quantity sold, and other factors. Industrial Minerals (London), December 1978 and December 1979, quoted price ranges as follows (converted from Canadian dollars and pounds sterling per metric ton to dollars per short ton):

	1978	1979
Canadian:		
Glass grade, 30 mesh, bulk car loss-truck lots, per short ton	NA	$19-$22
Ceramic grade, 200 mesh, bagged, 10-ton lots, per short ton	NA	36- 40
Norwegian:		
Glass grade, 32 mesh (Tyler), bulk, per short ton, c.i.f. main European port	$52-$53	64
Ceramic grade, 325 mesh (Tyler), bagged, per short ton, c.i.f. main European port	79	98

NA Not available.

In March 1978 and March 1979, the American Paint & Coatings Journal quoted paint-grade nepheline syenite in 50-pound bags, carload lots, f.o.b. Ontario, at $42.20 to $61.50 per ton.

Table 9.—U.S. imports for consumption of nepheline syenite

Year	Crude		Ground	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1977	860	$17	501,696	$9,118
1978	178	4	547,845	10,442
1979	2,260	28	533,700	10,818

APLITE

Aplite is another rock of granitic texture containing quartz mixed with varying proportions of soda or lime-soda feldspar; it is usually not suitable for use in ceramics but, if sufficiently low in iron, finds ready acceptance in the manufacture of glass, especially container glass. Japan, with an annual production of 400,000 to 500,000 tons, is the world's foremost producer of aplite.

Aplite of glassmaking quality was produced in the United States in 1978 only from two open pit operations in central Virginia. The Feldspar Corp. mined aplite near Montpelier, Hanover County, and treated the material by wet-grinding, classification, and spiraling to remove biotite, ilmenite, and rutile, followed by dewatering, drying, and high-intensity magnetic separation to eliminate iron-bearing minerals. IMC Chemical Group, Inc., operated an aplite mine near Piney River, Nelson County. The ferruginous material from this dry-ground ore is removed by a high-intensity magnetic process.

Domestic output in 1978 was 12% higher in tonnage than the previous year. In 1979, domestic output was 5% less in tonnage than in 1978. Specific annual data on aplite production, sales, and value are not released for publication. Aplite prices are not commonly quoted in trade journals, but the product traditionally commands a somewhat lower per-ton price than feldspar.

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[1] Physical scientist, Section of Nonmetallic Minerals.

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[4] Industrial Minerals (London). Company News & Mineral Notes. No. 129, June 1978, p. 55.

[5] ———. French Industrial Mineral Imports, 1976-77. No. 132, September 1978, p. 67.

[6] Dickson, T. Industrial Minerals of West Germany. Ind. Miner. (London), No. 131, August 1978, pp. 16-17, 24.

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[8] ———. U.K. 1977 Mineral Imports. No. 127, April 1978, p. 18.

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[10] ———. Durness In and Out. No. 134, November 1978, p. 14.

[11] Timberlake, R. C., and U. K. Custred (assigned to the American Cyanamid Co.). Process for Sizing and Desliming of Ore Matrix. U.S. Pat. 4,126,275, Nov. 21, 1978.

[12] Harben, P. The Spruce Pine Mining District, U.S.A. Ind. Miner. (London), No. 132, September 1978, pp. 23-27.

[13] Redeker, I. H. Flotation of Feldspar, Spodumene, Quartz, and Mica From Pegmatites in North Carolina, U.S.A. Erzmetall, Band 30, Heft 12, December 1977, pp. 566-572, English text.

[14] Heginbotham, J. H. Recovering Glass From Urban Refuse By Froth Flotation. BuMines RI 8227, 1978, 21 pp.

[15] Ceramic Industry. IMC Plans $5 Million Expansion of Nepheline Syenite Facility. V. 113, No. 2, August 1979, p. 16.

[16] Industrial Minerals (London). Indusmin's Expansions. No. 140, May 1979, p. 10.

[17] Harben, P. Nepheline Syenite; Indusmin and The Markets. Ind. Miner. (London), No. 144, September 1979, pp. 71-77.

[illegible]

APLITE.

[illegible]

Ferroalloys

By Frederick J. Schottman[1]

Production of ferroalloys in the United States increased in 1979 after declining each year from 1973 through 1978. Prices were generally higher in 1978 and 1979 owing to higher production costs and stronger markets.

Consumption of the bulk ferroalloys of silicon and manganese increased in 1978 and weakened in 1979 as total steel and cast iron production fell late in the year. Consumption of most ferroalloys used predominantly in alloy steels increased in both 1978 and 1979.

Exports of ferroalloys rose significantly in 1978 and 1979 but remained small compared with imports. Imports increased by about a fifth in 1978 but only slightly in 1979.

Legislation and Government Programs.—Eight ferroalloys were included in Government stockpiles. There were no changes in the inventories held during 1978 and 1979.

Table 1.—Ferroalloys produced and shipped from furnaces in the United States[1]

	1978				1979			
	Production		Shipments		Production		Shipments	
	Gross weight (short tons)	Alloy element contained (average percent)	Gross weight (short tons)	Value (thousands)	Gross weight (short tons)	Alloy element contained (average percent)	Gross weight (short tons)	Value (thousands)
Ferromanganese[2]	272,580	81	318,123	$145,827	317,102	80	330,487	$180,828
Silicomanganese	141,929	66	152,696	48,696	165,049	66	166,933	69,164
Ferrosilicon[3]	819,696	61	835,344	437,269	857,099	60	853,196	516,332
Chromium alloys:								
Ferrochromium:								
High-carbon	160,619	63	174,105	75,128	212,935	62	193,657	106,570
Low-carbon	15,082	69	20,325	21,401	34,034	69	35,991	43,457
Ferrochromium-silicon	23,710	36	31,831	17,000	25,898	36	36,009	23,166
Other alloys[4]	19,241	60	19,943	32,975	21,745	61	22,568	52,625
Total	218,652	60	246,204	146,504	294,612	60	288,225	[5]225,817
Ferrocolumbium	1,205	65	1,468	19,565	749	66	766	17,464
Ferrophosphorus	90,074	24	83,682	11,173	87,322	22	78,255	11,760
Other[6]	121,929	XX	146,801	223,289	153,124	XX	153,005	296,266
Grand total	1,666,017	XX	1,784,318	1,031,823	1,875,057	XX	1,870,967	1,317,631

XX Not applicable.

[1] Does not include alloys consumed in the making of other ferroalloys.

[2] Includes fused-salt electrolytic low-carbon ferromanganese (massive manganese).

[3] Includes silicon metal and miscellaneous silicon alloys.

[4] Includes chromium briquets, exothermic chromium additives, other miscellaneous chromium alloys, and chromium metal.

[5] Data do not add to total shown because of independent rounding.

[6] Includes ferroaluminum, ferroboron and other complex boron additive alloys, ferromolybdenum, ferronickel, ferrotitanium, ferrotungsten, ferrovanadium, ferrozirconium, spiegeleisen, silvery iron, and other miscellaneous alloys.

Table 2.—Producers of ferroalloys in the United States in 1978-79

Producer	Plant location	Products[1]	Type of furnace
Alabama Alloy Co., Inc	Bessemer, Ala	FeSi	Electric.
Aluminum Co. of America, Northwest Alloys, Inc.	Addy, Wash	Si, FeSi	Do.
Autlan Manganese Corp	Mobile, Ala	SiMn	Do.
AMAX Inc., Climax Molybdenum Co. Div.	Langeloth, Pa	FeMo	Metallothermic.
Cabot Corp., Kawecki-Berylco Industries, Inc.:			
National Metallurgical Div	Springfield, Oreg	Si	Electric.
Penn Rare Metals Div	Revere, Pa	FeCb	Metallothermic.
Chromasco Ltd., Chromium Mining & Smelting Corp. Div.	Woodstock, Tenn	FeCr, FeSi	Electric.
Engelhard Minerals & Chemicals Corp., Minerals and Chemicals Div.	Strasburg, Va	FeV	Metallothermic.
Foote Mineral Co., Ferroalloys Div.	Cambridge, Ohio Graham, W. Va Keokuk, Iowa	FeSi, FeV, silvery pig iron, other.[2]	Electric.
Hanna Mining Co., The:			
Hanna Nickel Smelting Co	Riddle, Oreg	FeNi, FeSi	Do.
Silicon Div	Wenatchee, Wash	Si, FeSi	Do.
Interlake, Inc., Globe Metallurgical Div.	Beverly, Ohio Selma, Ala	FeCr, FeCrSi, Si, FeSi, SiMn.	Do.
International Minerals & Chemical Corp., Industry Group, TAC Alloys Div.	Bridgeport, Ala Kimball, Tenn	FeSi	Do.
Macalloy Inc	Charleston, S.C	FeCr, FeCrSi	Do.
Metallurg, Inc., Shieldalloy Corp.	Newfield, N.J	FeAl, FeB, FeCb, FeTi, FeV, other.[2]	Metallothermic.
Ohio Ferro-Alloys Corp	Montgomery, Ala Philo, Ohio Powhatan Point, Ohio	FeB, FeMn, FeSi, Si, SiMn.	Electric.
Pennzoil Co., Duval Corp.	Sahuarita, Ariz	FeMo	Metallothermic.
Pesses Co., The	Newton Falls, Ohio Solon, Ohio Pulaski, Pa Fort Worth, Tex	FeAl, FeB, FeCb, FeMo, FeNi, FeTi, FeV, FeW, other.[2]	Electric and metallothermic.
Reactive Metals and Alloys Corp	West Pittsburg, Pa	FeTi, other[2]	Electric.
Reading Alloys, Inc	Robesonia, Pa	FeCb, FeV	Metallothermic.
Reynolds Metals Co	Sheffield, Ala	Si	Electric.
Satra Corp., Satralloy, Inc. Div.	Steubenville, Ohio	FeCr, FeCrSi, FeMn, FeSi.	Do.
SEDEMA S.A., Chemetals Corp.	Kingwood, W. Va	FeMn	Fused salt electrolytic.
SKW Alloys, Inc	Calvert City, Ky Niagara Falls, N.Y	FeMn, FeSi, SiMn.	Electric.
South African Manganese Amcor, Ltd. Roane Electric Furnace Co.	Rockwood, Tenn	FeMn, SiMn, FeSi.	Do.
Teledyne, Inc., Teledyne Wah Chang, Albany Div.	Albany, Oreg	FeCb	Metallothermic.
Union Carbide Corp., Metals Div.	Alloy, W. Va Ashtabula, Ohio Marietta, Ohio Niagara Falls, N.Y Portland, Oreg Sheffield, Ala	FeB, FeCr, FeCrSi, FeMn FeSi, FeV FeW, Si, SiMn, other.[2]	Electric.
Union Oil Co. of California, Molycorp, Inc.	Washington, Pa	FeB, FeMo, FeW.	Electric and metallothermic.
Ferrophosphorus:			
Electro-Phos Corp	Pierce, Fla	FeP	Electric.
FMC Corp., Industrial Chemical Div.	Pocatello, Idaho	FeP	Do.
Mobil Oil Corp., Mobil Chemical Co. Div.[3]	Nichols, Fla	FeP	Do.
Monsanto Co., Monsanto Industrial Chemicals Co.	Columbia, Tenn Soda Springs, Idaho	FeP	Do.
Occidental Petroleum Corp., Hooker Chemical Div., Hooker Chemicals & Plastics Corp.	Columbia, Tenn	FeP	Do.
Stauffer Chemical Co., Industrial Chemical Div.	Mt. Pleasant, Tenn Silver Row, Mont Tarpon Springs, Fla	FeP	Do.

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[1] FeAl, ferroaluminum; FeB, ferroboron; FeCb, ferrocolumbium; FeCr, ferrochromium; FeCrSi, ferrochromium-silicon; FeMn, ferromanganese; FeMo, ferromolybdenum; FeNi, ferronickel; FeP, ferrophosphorus; FeSi, ferrosilicon; FeTi, ferrotitanium; FeV, ferrovanadium; FeW, ferrotungsten; Si, silicon metal; SiMn, silicomanganese.

[2] Includes specialty silicon alloys, zirconium alloys, and miscellaneous ferroalloys.

[3] Ceased operation in 1978.

DOMESTIC PRODUCTION

After declining each year since 1972, total domestic production of ferroalloys reached a low in 1978 but increased in 1979. Production and shipments of most ferroalloys increased in 1979. Chromium alloy producers in particular benefited from a strong market and increased production by 35% in 1979. The Ferroalloys Association reported that its members used 8.5 billion and 9.9 billion kilowatt-hours of electric energy in 1978 and 1979, respectively.

Ownership of several ferroalloy producers changed in 1978 and 1979. In 1978, Airco, Inc., was purchased by BOC International, Ltd. The Theodore (Mobile), Ala., ferromanganese plant owned by Airco was shut down in 1978 and sold in 1979 to Minera Autlan S.A., a Mexican producer of manganese ore and ferroalloys. Airco left the ferroalloys business in 1979 when it sold its remaining ferroalloy plants. Süddeutsche Kalkstickstoff-Werke A.G. (SKW Trostberg), a company in the Federal Republic of Germany with ferroalloy plants in Germany and Canada, bought the Airco plants at Calvert City, Ky., and at Niagara Falls, N.Y. The plant at Charleston, S.C., was purchased by Macalloy Inc., a new company. In 1978, Kawecki Berylco Industries, Inc., was merged into Cabot Corp., and the Chemetals Division of Diamond Shamrock Corp. was purchased by SEDEMA S.A. of Belgium. In 1979, South African Manganese Amcor Ltd. (SAMANCOR) purchased the Roane Electric Furnace Co. plant at Rockwood, Tenn., from Engelhard Minerals & Chemicals Corp.

Table 3.—Consumption by end use of ferroalloys as additives in the United States[1]

(Short tons of alloys)

End use	FeMn	SiMn	FeSi	FeTi	FeP	FeB
1978						
Steel:						
Carbon	786,041	94,444	135,742	601	15,266	733
Stainless and heat-resisting	17,259	7,527	[2]47,010	1,960	6	23
Other alloy	169,729	38,977	[2]100,025	747	1,354	547
Tool	889	63	[2]3,441	W	--	W
Unspecified	893	2,603	19,290	--	--	--
Total steel[3]	974,811	143,614	305,508	3,308	16,626	1,303
Cast irons	23,972	16,365	418,470	144	7,460	9
Superalloys	476	W	498	52	W	25
Alloys (excluding alloy steels and superalloys)	16,411	2,596	70,105	207	82	101
Miscellaneous and unspecified	2,223	1,731	52,855	9	3,355	3
Total	1,017,893	164,308	847,431	3,720	27,523	1,441
Percent of 1977	111	111	107	101	76	118
1979						
Steel:						
Carbon	757,127	95,190	136,471	527	14,945	966
Stainless and heat-resisting	18,705	8,358	[2]58,962	2,202	([4])	46
Other alloy	186,528	44,733	[2]105,458	925	2,180	420
Tool	991	46	[2]3,519	([4])	([4])	W
Unspecified	1,192	3,179	20,998	5	10	--
Total steel[3]	964,543	151,506	325,398	3,659	17,135	1,432
Cast irons	21,494	15,716	328,830	120	8,405	W
Superalloys	483	--	458	98	--	30
Alloys (excluding alloy steels and superalloys)	16,308	2,386	77,237	196	125	80
Miscellaneous and unspecified	2,265	2,293	61,275	3	2,242	137
Total	1,005,088	171,901	793,198	4,076	27,908	1,679
Percent of 1978	99	105	94	110	101	117

W Withheld to avoid disclosing company proprietary data; included in "Miscellaneous and unspecified."

[1] FeMn, ferromanganese including spiegeleisen and manganese metal; SiMn, silicomanganese; FeSi, ferrosilicon including silicon metal, silvery pig iron, and inoculant alloys; FeTi, ferrotitanium; FeP, ferrophosphorus including other phosphorus materials; FeB, ferroboron including other boron materials.

[2] Part included in "Unspecified."

[3] Except for data withheld.

[4] Included in "Unspecified."

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CONSUMPTION AND USES

Consumption of most ferroalloys increased along with steel production in 1978 and 1979. However, demand weakened in late 1979, when steel and cast iron production was declining.

Consumption of manganese and silicon ferroalloys, which are used in many grades of steel and cast iron, followed the general trend of total steel production, which increased in 1978 and was little changed in 1979. However, a significant weakening in the market for cast iron, which is the largest end use for silicon ferroalloys, resulted in a 6% drop in total silicon ferroalloy consumption between 1978 and 1979.

Consumption of ferrochromium and ferronickel, which are used predominantly in alloy steels and especially in stainless steels, rose in both 1978 and 1979.

Despite strong demand for molybdenum, consumption of ferromolybdenum increased only slightly because of limited supplies. Consumption of ferrovanadium and ferrocolumbium increased with higher production of high-strength low-alloy steels. Because of the shortage of molybdenum, users were encouraged to substitute vanadium- or columbium-bearing grades of steel when practical.

Table 4.—Consumption by end use of ferroalloys as alloying elements in the United States[1]

(Short tons of contained elements)

End use	FeCr	FeMo	FeW	FeV	FeCb	FeNi
1978						
Steel:						
Carbon	4,676	113	--	1,020	692	--
Stainless and heat-resisting	201,318	582	55	32	403	25,676
Other alloy	59,122	1,072	54	[3]3,946	1,141	4,436
Tool	4,199	455	257	858	2	(5)
Unspecified	W	W	--	W	3	--
Total steel[4]	269,215	2,222	366	5,856	2,241	30,112
Cast irons	9,943	1,476	(5)	58	--	237
Superalloys	11,010	157	14	22	573	591
Alloys (excluding alloy steels and superalloys)	5,566	497	35	[2]11	30	2,282
Miscellaneous and unspecified	2,242	92	1	50	3	50
Total	297,976	4,444	416	5,997	2,847	33,272
Percent of 1977	111	105	88	128	130	106
1979						
Steel:						
Carbon	4,607	97	--	1,096	713	--
Stainless and heat-resisting	222,759	643	64	45	414	31,710
Other alloy	62,243	1,100	67	3,932	[6]1,129	4,680
Tool	3,434	391	227	852	(7)	(5)
Unspecified	W	W	(5)	W	6	--
Total steel[4]	293,043	2,231	358	5,925	2,262	36,390
Cast irons	9,777	1,369	--	62	--	263
Superalloys	12,510	198	25	16	888	742
Alloys (excluding alloy steels and superalloys)	6,026	526	7	[2]10	16	2,580
Miscellaneous and unspecified	2,177	106	2	55	3	1
Total	323,533	4,430	392	6,068	3,169	39,977
Percent of 1978	109	100	94	101	111	120

W Withheld to avoid disclosing company proprietary data; included in "Miscellaneous and unspecified."

[1] FeCr, ferrochromium including other chromium ferroalloys and chromium metal; FeMo, ferromolybdenum including calcium molybdate; FeW, ferrotungsten including melting base self-reducing tungsten; FeV, ferrovanadium including other vanadium-carbon-iron ferroalloys; FeCb, ferrocolumbium including nickel columbium; FeNi ferronickel.

[2] Part included in "Miscellaneous and unspecified."

[3] Included with "Other alloy."

[4] With minor exceptions as denoted by W and footnote 2 where applicable.

[5] Less than 1/2 unit.

[6] Part included in "Unspecified."

[7] Included in "Unspecified."

Table 5.—Stocks of ferroalloys held by producers and consumers in the United States at yearend

(Short tons)

	Producer		Consumer		Total	
	1978 (gross weight)	1979 (gross weight)	1978 (gross weight)	1979 (gross weight)	1978 (gross weight)	1979 (gross weight)
Manganese ferroalloys[1]	84,866	61,028	200,486	198,967	285,352	254,990
Silicon alloys[2]	115,464	116,404	65,443	55,129	180,907	171,533
Ferrochromium[3]	47,887	48,861	81,761	58,314	129,648	107,175
Ferroboron[4]	115	W	355	402	470	402
Ferrophosphorus[5]	62,625	67,042	4,642	3,964	67,267	71,006
Ferrotitanium	W	W	855	595	855	595
Total	310,957	293,330	353,542	312,371	664,499	605,701
	1978 (contained element)	1979 (contained element)	1978 (contained element)	1979 (contained element)	1978 (contained element)	1979 (contained element)
Ferrocolumbium[6]	156	151	472	662	628	813
Ferromolybdenum[7]	242	310	932	936	1,174	1,246
Ferronickel	W	W	5,575	2,467	5,575	2,467
Ferrotungsten[8]	W	W	140	75	140	75
Ferrovanadium[9]	838	1,062	900	879	1,738	1,941
Total	1,236	1,523	8,019	5,019	9,255	6,542

W Withheld to avoid disclosing company proprietary data.

[1] Includes ferromanganese, silicomanganese, and manganese metal.

[2] Includes ferrosilicon, miscellaneous silicon alloys, and silicon metal.

[3] Includes other chromium alloys and chromium metal.

[4] Consumer totals include other boron materials.

[5] Consumer totals include other phosphorus materials.

[6] Consumer totals include nickel columbium.

[7] Consumer totals include calcium molybdate.

[8] Consumer totals include melting base self-reducing tungsten.

[9] Includes other vanadium-iron-carbon ferroalloys.

PRICES

Prices for most ferroalloys increased in 1978 and 1979, pushed up by higher production costs. In general, price increases were larger in 1979 than in 1978 because of a stronger market due to higher world steel production. However, several alloys did not follow the general trend.

Prices for ferrochromium were depressed in 1978 by the availability of low-cost imported alloys. Late in 1978 and in 1979, prices rose because of stronger demand, higher production costs, and a special duty imposed on low-cost high-carbon ferrochromium imports.

Molybdenum was in short supply in both 1978 and 1979, and prices for ferromolybdenum increased by two-thirds. Molybdenum was on allocation to consumers, and free market dealer prices for ferromolybdenum were over four times producer prices in mid-1979.

The supply of nickel products was ample in 1978, and prices declined while producers reduced output and stocks. With higher demand and lower stocks in 1979, prices increased rapidly.

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Alloy	End of year price[1]	
	1978	1979
Charge chromium (66% to 70%)	$0.41	$0.46
Low-carbon ferrochromium, 0.02% maximum carbon ("Simplex")	.80	.90
Standard 78% ferromanganese, per long ton of alloy	440.00	490.00
Ferromolybdenum, lump	6.38	8.40
Ferronickel	1.88	2.95
Ferrosilicon, 50%	.355	.42
Ferrosilicon, 75%	.3925	.4625

[1] Per pound contained, except as noted otherwise. If range of prices was quoted, the lowest price is shown.

Source: Metals Week.

FOREIGN TRADE

Exports of ferroalloys increased significantly in both 1978 and 1979, more than doubling in quantity and value between 1977 and 1979. In that period, there were large increases in exports of ferromanganese, ferrosilicon, and ferrophosphorus. Despite the increase, however, exports in 1979, on a gross weight basis, were about one-twelfth of imports.

Table 6.—U.S. exports of ferroalloys

Alloy	1977		1978		1979	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Ferrocerium and alloys	260	$1,043	19	$214	42	$273
Ferrochromium	12,472	7,268	19,397	10,727	14,762	14,558
Ferromanganese	6,051	3,391	9,433	4,769	25,344	19,252
Silicomanganese	(1)	(1)	4,782	1,568	5,243	2,627
Ferromolybdenum	798	4,863	733	6,721	840	10,029
Ferrophosphorus	2,381	297	4,168	696	37,292	3,678
Ferrosilicon	10,548	6,085	11,900	7,871	22,357	14,740
Ferrotungsten	2	31	(2)	(2)	(2)	(2)
Ferrovanadium	658	4,954	1,309	9,986	879	7,881
Ferroalloys, n.e.c	7,982	8,558	13,937	9,356	6,441	12,616
Spiegeleisen	40	13	--	--	--	--
Total[3]	41,192	36,453	65,678	51,908	113,200	85,655

[1] Not recorded separately prior to 1978.
[2] Included with ferroalloys, n.e.c. after 1977.
[3] Data may not add to totals shown because of independent rounding.

Table 7.—U.S. imports for consumption of ferroalloys and ferroalloy metals

Alloy	1978			1979		
	Gross weight (short tons)	Content (short tons)	Value (thousands)	Gross weight (short tons)	Content (short tons)	Value (thousands)
Manganese alloys:						
Ferromanganese containing less than 1% carbon	3,645	3,165	$2,842	2,238	1,955	$1,998
Ferromanganese containing over 1% and less than 4% carbon	31,067	25,957	14,610	52,538	42,588	30,249
Ferromanganese containing 4% or more carbon	644,886	502,074	160,398	766,437	594,192	224,596
Ferrosilicon-manganese (Mn content)	94,644	63,194	26,453	94,671	62,606	34,756
Total manganese alloys	775,042	594,390	204,298	915,884	701,843	291,599
Ferrosilicon:						
8%-30% silicon	4,915	728	596	4,491	666	575
30%-60% silicon, over 2% magnesium	(1)	(1)	(1)	12,127	5,768	7,169
30%-60% silicon, n.e.c.[1]	45,598	21,826	16,118	14,350	7,298	7,137
60%-80% silicon	84,687	63,007	32,992	82,122	60,352	42,540
80%-90% silicon	291	241	90	463	389	200
Over 90% silicon	129	120	90	--	--	--
Total ferrosilicon[2]	135,620	85,922	49,881	113,553	74,473	57,621
Chromium alloys:						
Ferrochromium containing 3% or more carbon	310,941	171,113	99,274	221,831	121,888	94,337
Ferrochromium containing less than 3% carbon	16,043	11,189	14,259	20,631	14,120	22,254
Ferrosilicon-chromium	551	110	51	42	3	21
Total chromium alloys	327,535	182,412	113,584	242,504	135,961	116,612
Ferronickel	74,860	(3)	74,724	62,598	18,776	91,340
Other ferroalloys:						
Ferrocerium and other cerium alloys	65	(3)	641	62	(3)	680
Ferromolybdenum	182	131	1,499	31	23	636
Ferrophosphorus	--	--	--	6	(3)	8
Ferrotitanium and ferrosilicon titanium	863	(3)	1,415	964	(3)	2,702
Ferrotungsten and ferrosilicon tungsten	361	287	5,206	368	285	5,228
Ferrovanadium	565	391	4,086	737	517	5,967
Ferrozirconium	1,129	471	943	2,013	(3)	2,046
Ferroalloys, n.e.c.[4]	3,275	(3)	17,959	4,477	(3)	26,067
Total other ferroalloys	6,440	XX	31,749	8,658	XX	43,334
Total ferroalloys[2]	1,319,496	XX	474,228	1,348,192	XX	600,506
Metals:						
Manganese	9,113	(3)	7,857	6,683	(3)	5,545
Silicon (96%-99% silicon)	28,732	(3)	19,325	19,936	(3)	16,833
Silicon (99%-99.7% silicon)	6,239	6,174	4,786	7,050	6,987	6,646
Chromium	3,613	(3)	16,650	3,661	(3)	19,889
Total ferroalloy metals	47,697	XX	48,618	37,330	XX	48,913
Grand total	1,367,193	XX	522,856	1,380,522	XX	649,419

XX Not applicable.

[1] Prior to 1979, magnesium ferrosilicon was included in the class for ferrosilicon with 30%-60% silicon.

[2] Data may not add to totals shown because of independent rounding.

[3] Not recorded.

[4] Principally ferrocolumbium.

Total imports of ferroalloys, on a gross weight basis, increased by 20% between 1977 and 1978, but only slightly between 1978 and 1979. Imports of manganese ferroalloys continued to increase their dominance of the U.S. market. Imports of ferrosilicon and ferrochromium increased in 1978 but declined in 1979. Higher demand and prices for those alloys in major steelmaking countries made the U.S. market less attractive to exporters. Also, a special duty on low-priced high-carbon ferrochromium raised the import price of that alloy in 1979.

The major source of imported ferroalloys

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was the Republic of South Africa which supplied about two-fifths of the total tonnage. Europe supplied about a third and countries of the Western Hemisphere supplied about a sixth of the total. Major exporting countries included France, Norway, Yugoslavia, Canada, and Brazil.

In 1978, the International Trade Commission found that the domestic ferrochromium industry was being seriously injured by imports and recommended a temporary extra duty on high-carbon ferrochromium. The President ordered an extra 4-cent-per-pound duty to be collected on imports of high-carbon ferrochromium valued at less than 38 cents per pound of contained chromium.

The Department of the Treasury determined in late 1979 that Spain was subsidizing exports of high- and medium-carbon ferromanganese, silicomanganese, high-carbon ferrochromium, and 60% to 80% ferrosilicon. Countervailing duties equal to the subsidies (2.4% ad valorem on medium-carbon ferromanganese and 3.36% on the other alloys) were imposed. In a similar investigation, the Department made a preliminary finding that Brazil was subsidizing the export of four ferroalloys.

The Department of the Treasury determined in a dumping case that SKW Canada, Ltd., was selling silicon metal in the United States at less than fair value based on production costs. No additional duties were imposed, however, because the International Trade Commission decided that the imports had not harmed and did not threaten the domestic industry.

In early 1978, the Administration rejected a request from domestic producers that high-carbon ferromanganese, silicomanganese, and 60% to 80% ferrosilicon be removed from the list of items allowed duty-free entry to the United States under the Generalized System of Preferences (GSP). A request from Yugoslavia that one grade of silicon metal be added to the GSP list was also rejected.

WORLD REVIEW

Brazil.—Brazilian production and capacity for ferroalloys continued to expand with production of 524,000 short tons in 1979, up 28% from that in 1978. Companhia Brasileira de Metalúrgia e Mineração (CBMM), the market economy countries' largest producer of columbium, announced a major expansion of its columbium and ferrocolumbium capacity. Columbium oxide capacity will expand from 32 million to 55 million pounds by early 1981.

Colombia.—Construction on the Cerro Matoso nickel project began in 1979. The mine and smelter, with a capacity of 42 million pounds of nickel contained in ferronickel, is expected to begin operation in 1982. In 1978 the ownership of the project was reorganized, and the share owned by a subsidiary of The Hanna Mining Co. was reduced from 66% to 20%.

France.—The ferromanganese plant of the nearly bankrupt Aciéries de Paris et D'Outreau, Western Europe's largest ferromanganese producer, was taken over by a new company, Société du Ferromanganese Paris-Outreau. United States Steel Corp., which had a 27% interest in Aciéres de Paris et d'Outreau, has an indirect interest in the new company through one of the partners of the new company.

Greece.—Hellenic Ferro Alloys, a newly formed subsidiary of the Government-sponsored Hellenic Industrial & Mining Investment Co., S.A., plans to build a 33,000-ton-per-year ferrochromium plant at Tsiggeli, with operation to begin in 1982. During 1979, Soc. Minière et Metallurgique de Larymna S.A. (LARCO) completed the expansion of its ferronickel operation from a capacity of 17,000 tons per year to 30,000 tons per year. However, because of energy problems, plans have been postponed for further expansion by LARCO and for a new nickel smelter by Eleusis Bauxite Mines.

Iceland.—The first furnace at the new Icelandic Alloys Ltd. ferrosilicon plant began operation in 1979. The second furnace should be started in late 1980, bringing the plant to a capacity of 55,000 tons of 75% ferrosilicon per year. The company is owned 55% by the Government of Iceland and 45% by Elkem-Spigerverket A/S.

India.—Because of a severe power shortage, India's ferroalloy industry was forced to cut back production in late 1979. India is normally a net exporter, but late in the year exports of ferrosilicon and ferromanganese were banned in order to conserve supplies for domestic consumers.

Indonesia.—The partners in P.T. Pacific Nickel Indonesia deferred plans for a nickel mining and smelting operation because of depressed nickel prices. U.S. companies with interest in the project were United States Steel Corp. and Amoco Minerals Co.

division of Standard Oil Co. of Indiana.

Japan.—Faced with relatively high power costs, Japanese ferroalloy producers shut down several small obsolescent furnaces to bring capacity better in line with demand. Capacity for ferrosilicon, the most power-intensive bulk ferroalloy, was reduced by about 20%, or 110,000 tons per year.

Norway.—Elkem-Spigerverket A/S was adding a furnace at Bremenager to double its silicon metal capacity there to 27,000 tons per year. Orkla Industrier A/S is planning to increase its ferrosilicon capacity from 24,000 tons per year to 66,000 tons per year after reaching agreement with the Government for long-term power.

South Africa, Republic of.—Tubatse Ferrochrome (Pty.) Ltd., 49% owned by Union Carbide Corp., started its third ferrochromium furnace, adding 40,000 tons per year of capacity. The South African ferrochromium industry operated near capacity in early 1979 as it used its economic advantages to increase its share of a relatively strong world market for ferrochromium.

Yugoslavia.—Tovarna dusika Ruse is installing an 18,000-ton-per-year (75% grade) ferrosilicon furnace at its plant at Ruse in Slovenia. Two new ferronickel projects at Kavadarci and Glogovac are expected to start production in 1981 and 1982, respectively.

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[1] Physical scientist, Section of Ferrous Metals.

Table 8.—Ferroalloys: World production, by country, furnace type, and alloy type

(Thousand short tons)

Country,[1] furnace type,[2] and alloy type[3]	1976	1977	1978[p]	1979[e]
Argentina: Electric furnace:[4]				
Ferromanganese	26	31	28	34
Silicomanganese	[r]7	7	11	13
Ferrosilicon	[r]19	17	11	18
Other	1	1	1	1
Total	[r]53	56	51	66
Australia: Electric furnace:[4]				
Ferromanganese	55	78	79	79
Silicomanganese	16	26	27	27
Ferrosilicon	[r]8	21	21	21
Total	[r]79	125	127	127
Austria: Electric furnace, undistributed	9	8	8	10
Belgium: Electric furnace, ferromanganese[5]	93	61	96	100
Brazil: Electric furnace:				
Ferromanganese	[r]109	142	130	[e]147
Silicomanganese	70	83	117	[e]141
Ferrosilicon	50	66	80	[e]74
Silicon metal[7]	6	5	6	[e]6
Ferrochromium	66	78	69	[e]93
Ferrochromium-silicon	[r]6	5	5	[e]8
Ferronickel	11	12	12	[e]13
Other	[r]22	23	22	[e]42
Total[8]	[r]340	409	451	[e]524
Bulgaria: Electric furnace:				
Ferromanganese[5] [6]	36	33	31	31
Ferrosilicon[6]	28	21	19	18
Other[6]	1	1	1	1
Total	[r]65	55	51	50
Canada: Electric furnace:				
Ferromanganese[5] [6]	[r]88	66	77	55
Ferrosilicon	[r]94	[e]126	143	115
Silicon metal[7]	[e]22	[e]25	31	[e]29
Other[10] [6]	[r]60	13	25	10
Total	[r]264	[e]230	[e]276	209

See footnotes at end of table.

Table 8.—Ferroalloys: World production, by country, furnace type, and alloy type —Continued

(Thousand short tons)

Country,[1] furnace type,[2] and alloy type[3]	1976	1977	1978[p]	1979[e]
Chile: Electric furnace:				
Ferromanganese	9	5	[e]5	4
Silicomanganese	2	([11])	([e] [11])	1
Ferrosilicon	5	3	[e]3	3
Other	1	1	[e]1	1
Total	17	9	[e]9	9
China:[e]				
Mainland: Furnace type unspecified:				
Ferromanganese[e] [9]	210	255	340	375
Ferrosilicon[e]	110	120	165	180
Silicon metal[7] [e]	5	5	9	10
Ferrochromium[e]	65	80	100	100
Other[e] [10]	30	40	46	55
Total[e]	[r]420	500	660	720
Taiwan: Electric furnace, ferrosilicon	[r]26	27	33	[e]41
Colombia: Electric furnace, ferrosilicon[12]	1	[e]1	[e]1	[e]1
Czechoslovakia:				
Blast furnace, undistributed	2	--	--	--
Electric furnace:				
Ferromanganese[e] [9]	77	110	110	110
Ferrosilicon[e]	30	39	39	36
Silicon metal[7] [e]	4	5	6	6
Ferrochromium[e]	33	33	33	31
Other[e] [10]	10	11	13	10
Total[e] [12]	[r]156	198	201	193
Dominican Republic: Electric furnace, ferronickel	75	79	41	55
Egypt: Electric furnace:				
Ferrosilicon	--	5	[e]5	6
Other	5	--	--	--
Total	5	5	[e]5	6
Finland: Electric furnace, ferrochromium	44	37	49	[e]49
France:				
Blast furnace:				
Spiegeleisen	--	10	7	[e]4
Ferromanganese	[r]402	395	430	[e]485
Electric furnace:				
Silicomanganese[14]	13	23	21	[e]15
Ferrosilicon	261	266	219	[e]298
Silicon metal	45	47	46	50
Ferrochromium[15]	112	114	106	[e]106
Other[16]	[r]113	134	137	[e]152
Total[e]	[r]946	989	966	1,110
German Democratic Republic:				
Blast furnace, spiegeleisen	--	--	4	--
Electric furnace:				
Ferromanganese[e] [9]	88	98	88	88
Ferrosilicon[e]	25	22	34	33
Silicon metal[e] [7]	3	3	4	4
Ferrochromium[e]	32	26	28	23
Other[e] [10]	22	21	23	22
Total[e] [11]	[r]170	170	181	170
Germany, Federal Republic of:				
Blast furnace:				
Ferromanganese (including spiegeleisen)	243	193	231	[e]257
Ferrosilicon	100	96	86	[e]87
Electric furnace:				
Ferromanganese[e] [9]	66	55	17	28
Ferrosilicon[e]	66	55	33	44
Ferrochromium[e]	66	61	55	66
Other[e] [10]	65	60	48	55
Total	606	520	470	537

See footnotes at end of table.

Table 8.—Ferroalloys: World production, by country, furnace type, and alloy type —Continued

(Thousand short tons)

Country,[1] furnace type,[2] and alloy type[3]	1976	1977	1978[p]	1979[e]
Greece: Electric furnace, ferronickel	67	39	61	[e]60
Hungary: Electric furnace:				
Ferromanganese[e]	3	3	3	3
Ferrosilicon	8	8	8	8
Silicon metal[e 7]	2	2	2	2
Total[e 13]	[r]13	13	13	13
Iceland: Electric furnace, ferrosilicon	--	--	--	17
India: Electric furnace:				
Ferromanganese	194	213	243	226
Silicomanganese	(11)	3	3	3
Ferrosilicon	59	49	58	50
Silicon metal[7]	NA	1	(11)	1
Ferrochromium	19	20	24	21
Ferrochromium-silicon	6	5	4	4
Other	(11)	9	1	1
Total[e]	278	300	333	306
Italy:				
Blast furnace:				
Spiegeleisen	3	7	3	[e]3
Ferromanganese	69	64	68	[e]74
Electric furnace:				
Ferromanganese	17	19	30	[e]24
Silicomanganese	46	44	47	[e]60
Ferrosilicon	87	84	75	89
Silicon metal[7]	19	[e]18	16	17
Ferrochromium	50	44	41	47
Ferrochromium-silicon	(17)	--	(17)	(17)
Other[15]	[15]7	9	[15]9	[15]12
Total[e 15]	[r]298	289	289	326
Japan: Electric furnace:				
Ferromanganese	697	581	502	[e]665
Silicomanganese	411	368	334	[e]330
Ferrosilicon	345	321	298	[e]352
Silicon metal[7]	49	41	16	[e]17
Ferrochromium	511	440	362	[e]402
Ferrochromium-silicon	12	12	10	22
Ferronickel	[r]220	247	219	[e]299
Other	[r]17	23	22	26
Total[e]	[r]2,262	2,033	1,703	[e]2,113
Korea, North: Furnace type unspecified:				
Ferromanganese[18 e]	44	62	72	72
Ferrosilicon[e]	22	25	33	33
Other[10 e]	11	13	15	15
Total[e]	[r]77	[r]100	120	120
Korea, Republic of: Electric furnace:				
Ferromanganese[e]	[r]32	40	52	78
Ferrosilicon	38	30	34	44
Other[e 7]	1	1	1	1
Total	[r]71	71	87	123
Mexico: Electric furnace:				
Ferromanganese	60	110	118	132
Silicomanganese	19	30	37	39
Ferrosilicon	20	25	27	28
Ferrochromium	4	3	5	4
Other	(11)	(11)	1	1
Total	103	168	188	204
New Caledonia: Electric furnace, ferronickel	173	[r e]127	[e]89	92

See footnotes at end of table.

Table 8.—Ferroalloys: World production, by country, furnace type, and alloy type —Continued

(Thousand short tons)

Country,[1] furnace type,[2] and alloy type[3]	1976	1977	1978[p]	1979[e]
Norway: Electric furnace:				
Ferromanganese	[r]384	269	305	[e]373
Silicomanganese	186	140	149	[e]198
Ferrosilicon	306	246	296	[e]385
Silicon metal[7] [e]	63	56	70	[e]77
Ferrochromium	35	25	16	[e]13
Ferrochromium-silicon	1	(11)	1	([e] 11)
Other[10]	34	34	7	[e]8
Total[8] [12]	[r]1,009	770	844	[e]1,054
Peru: Electric furnace:				
Ferromanganese	--	--	1	1
Ferrosilicon	(11)	(11)	(11)	1
Total	(11)	(11)	1	2
Philippines: Electric furnace, ferrosilicon[19] [e]	8	17	15	20
Poland:				
Blast furnace:				
Spiegeleisen	9	12	8	10
Ferromanganese	128	136	131	133
Electric furnace:				
Ferromanganese[8] [e]	50	55	55	55
Ferrosilicon[e]	57	61	58	57
Silicon metal[e] [7]	12	12	12	12
Ferrochromium[e]	55	55	55	55
Other[10] [e]	19	21	18	15
Total[8] [12]	[r]330	352	337	337
Portugal: Electric furnace:				
Ferrosilicon[e]	[r]8	15	13	18
Silicon metal[e] [7]	--	15	17	35
Other[e]	[r]2	3	2	4
Total[8] [12]	[r]10	33	32	57
Rhodesia, Southern: Electric furnace, ferrochromium[e]	205	220	220	220
South Africa, Republic of: Furnace type unspecified:				
Ferromanganese[e]	386	441	530	806
Silicomanganese[e]	24	28	33	50
Ferrosilicon[e]	87	110	132	154
Silicon metal[e] [7]	25	31	36	39
Ferrochromium[e]	386	419	496	661
Ferrochromium-silicon[e]	24	32	34	46
Other[e] [20]	[r](11)	(11)	(11)	1
Total[8] [12]	[r]932	1,061	1,261	[e]1,756
Spain: Electric furnace:				
Ferromanganese	[r]147	156	153	160
Silicomanganese	100	70	123	121
Ferrosilicon	[r]62	75	112	132
Silicon metal[7] [e]	7	18	22	22
Ferrochromium	[r]22	18	15	22
Other	(11)	(11)	(11)	1
Total[8] [12]	[r]338	337	425	458
Sweden: Electric furnace:				
Silicomanganese	8	--	--	--
Ferrosilicon	41	25	--	--
Silicon metal[7]	20	14	[e]18	18
Ferrochromium	128	148	[e]195	206
Ferrochromium-silicon	7	9	[e]22	22
Other	3	2	[e]3	3
Total[8] [12]	[r]207	198	236	[e]251
Switzerland: Electric furnace:				
Ferrosilicon[e]	6	6	6	6
Silicon metal[7] [e]	3	3	3	3
Total[8] [e]	[r]9	9	9	9

See footnotes at end of table.

Table 8.—Ferroalloys: World production, by country, furnace type, and alloy type—Continued

(Thousand short tons)

Country,[1] furnace type,[2] and alloy type[3]	1976	1977	1978[p]	1979[e]
Thailand: Electric furnace:				
Ferromanganese	2	1	1	[e]2
Ferrosilicon	1	--	2	[e]3
Total	3	1	3	[e]5
Turkey: Electric furnace:				
Ferromanganese[e]	--	1	1	1
Ferrosilicon[e]	--	3	3	3
Ferrochromium[e]	28	38	44	55
Total[e]	28	42	48	59
U.S.S.R.:				
Blast furnace:				
Spiegeleisen	112	110	110	110
Ferromanganese	937	937	970	959
Other	31	28	33	33
Electric furnace:[21]				
Ferromanganese[e]	99	105	110	132
Silicomanganese[e]	28	33	33	33
Ferrosilicon[e]	[r]661	661	683	694
Silicon metal[7] [e]	50	52	52	63
Ferrochromium[e]	231	231	243	254
Ferrochromium-silicon[e]	6	6	6	6
Other[16]	193	198	204	204
Total[8]	[r]2,348	2,361	2,444	2,488
United Kingdom:				
Blast furnace, ferromangese	134	107	76	135
Electric furnace, undistributed[e]	18	16	18	18
Total	[r]152	123	94	153
United States: Furnace type unspecified:[22]				
Ferromanganese	483	334	273	[e]317
Silicomanganese	129	120	142	[e]165
Ferrosilicon[23]	[r]732	776	703	[e]679
Silicon metal[23]	129	118	116	[e]145
Ferrochromium	215	217	195	[e]269
Ferrochromium-silicon	54	53	24	[e]26
Other[24]	168	136	213	[e]274
Total	1,910	1,754	1,666	[e]1,875
Uruguay: Electric furnace ferrosilicon	([11])	([11])	--	--
Venezuela: Electric furnace, ferrosilicon	3	22	39	45
Yugoslavia: Electric furnace:				
Ferromanganese	24	60	[e]71	83
Silicomanganese	29	10	[e]11	11
Ferrosilicon	[25]109	61	[e]71	77
Silicon metal[7]	([25])	30	[e]35	39
Ferrochromium	47	40	[e]46	55
Ferrochromium-silicon	8	6	[e]7	9
Other	4	2	[e]2	2
Total[8]	221	209	243	[e]276
Grand total	[r]14,424	14,128	14,476	16,416
Of which:				
Blast furnace:				
Spiegeleisen[26]	124	189	132	127
Ferromanganese[26]	[r]1,918	1,882	1,906	2,043
Other[27]	[r]131	124	119	120
Undistributed	[r]2	--	--	--
Total blast furnace	[r]2,170	2,095	2,157	2,290
Electric furnace:[28]				
Ferromanganese[29]	[r]2,356	2,292	2,306	2,611
Silicomanganese[29] [30]	[r]1,088	985	1,088	1,207

See footnotes at end of table.

Table 8.—Ferroalloys: World production, by country, furnace type, and alloy type —Continued

(Thousand short tons)

Country,[1] furnace type,[2] and alloy type[3]	1976	1977	1978[p]	1979[e]
Of which: —Continued				
Electric furnace:[28] —Continued				
Ferrosilicon	[r]3,383	3,409	3,472	3,783
Silicon metal	464	501	517	595
Ferrochromium[31]	[r]2,354	2,342	2,337	2,754
Ferrochromium-silicon[31]	[r]124	128	111	143
Ferronickel[32]	[r]546	504	422	519
Other[32]	[r]789	756	825	917
Undistributed	[r]27	24	26	28
Total electric furnace	[r]11,131	10,941	11,104	12,557
Furnace type unspecified:				
Ferromanganese and total	[r]1,123	1,092	1,215	1,569

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[e] Estimate. [p] Preliminary. [r] Revised. NA Not available.

[1] In addition to the countries listed, Romania is known to produce electric furnace ferroalloys, but output is not reported quantitatively and no basis is available for estimation.

[2] To the extent possible, ferroalloy production of each country has been separated according to the furnace type from which production is obtained; production derived from metallothermic operations is included with electric furnace production.

[3] To the extent possible, ferroalloy production of each country has been separated so as to show individually the following major types of ferroalloys: Spiegeleisen, ferromanganese, silicomanganese, ferrosilicon, silicon metal (added to this year's edition), ferrochromium, ferrochromium-silicon, and ferronickel. Ferroalloys other than those listed that have been identified specifically in sources, as well as those ferroalloys not identified specifically but which definitely exclude those listed previously in this footnote have been reported as under other. For countries for which one or more of the individual ferroalloys listed separately in this footnote have been inseparable from some other ferroalloys owing to the Nation's reporting system, such deviations are indicated by individual footnote. In instances where ferroalloy production has not been subdivided in sources, and where no basis is available for estimation of individual component ferroalloys, the entry has been reported as "Undistributed."

[4] Data for year ending November 30 of that stated.

[5] Reported as blast furnace ferromanganese and spiegeleisen but believed to be electric furnace output.

[6] Reported figure.

[7] Included for the first time in this edition.

[8] Series revised to include silicon metal.

[9] Includes silicomanganese.

[10] Includes ferrochromium-silicon and ferronickel, if any was produced.

[11] Less than 1/2 unit.

[12] Colombia is reported to also produce ferromanganese, but output is not reported quantitatively and no basis is available for estimation.

[13] Total for 1976-78 represents an estimate for silicon metal plus a reported total for all other types.

[14] Includes silicospiegeleisen.

[15] Includes ferrochromium-silicon, if any was produced.

[16] Includes ferronickel, if any was produced.

[17] Included with other if any was produced.

[18] Series revised to exclude calcium silicide.

[19] Based on exports; additional quantities may be consumed in the Philippines.

[20] Ferrovanadium only; other minor ferroalloys may be produced, but no basis is available for estimation.

[21] Soviet production of electric furnace ferroalloys is not reported; estimates provided are based on crude source material production and availability for consumption (including estimates) and upon reported ferroalloy trade.

[22] U.S. production of ferromanganese cannot be separated by furnace type in order to conceal corporate proprietary information. Similarly, spiegeleisen and ferronickel production cannot be separately reported. All U.S. ferroalloy production except a portion of ferromanganese output is from electric furnaces or metallothermic operations.

[23] In previous editions, silicon metal was included with ferrosilicon.

[24] Includes spiegeleisen and ferronickel.

[25] Silicon metal apparently included with ferrosilicon.

[26] Spiegeleisen for the Federal Republic of Germany is included with blast furnace ferromanganese.

[27] Includes the following quantities specifically identified as ferrosilicon: 1976—100; 1977—96; 1978—86; 1979—87. The remainders are not identified except that they are not spiegeleisen or ferromanganese.

[28] Although furnace type has not been specified for any ferroalloy production for mainland China, North Korea, the Republic of South Africa, and the United States, all output of these countries has been included under electric furnace (and metallothermic) output except for their production of ferromanganese, which is reported separately below.

[29] Ferromanganese includes silicomanganese (if any was produced) for countries carrying footnote 9 on ferromanganese data line.

[30] Includes silicospiegeleisen for France.

[31] Ferrochromium includes ferrochromium-silicon (if any was produced) for countries carrying footnote 15 on ferrochromium data line.

[32] Other includes ferronickel production for France, Norway, the U.S.S.R., and the United States.

Fluorspar

By Dennis S. Kostick and Ronald J. DeFilippo[1]

Shipments of domestically produced fluorspar continued a third year of decline in 1979, reaching the lowest level in over 40 years. The pattern of fluorspar consumption remained nearly unchanged from 1978 except in the steel industry, where there was a decline in total production. The United States depended on imports to supply over 85% of its fluorspar requirements in 1978-1979. Mexico was the largest supplier of fluorspar to the United States, followed by the Republic of South Africa, Italy, and Spain.

Legislation and Government Programs.—Due to continued uncertainty over the role of chlorofluorocarbons (CFC's) in the depletion of stratospheric ozone, the U.S. Consumer Product Safety Commission (CPSC) required that effective February 20, 1978, certain "nonessential" aerosol spray products that contain CFC's were to carry a warning label. The label advised consumers that the use of CFC's was potentially harmful to the ozone layer.[2] The Environmental Protection Agency (EPA); CPSC; Department of Health, Education, and Welfare; and the Food and Drug Administration then ordered a ban on the manufacturing and packaging of such products effective December 15, 1978, and the total removal of these products from interstate commerce effective April 15, 1979.[3] EPA later emphasized that CFC's could not be used in the aerosol products covered by the ban even when the CFC's were part of the product mix and not serving as the main propellent.[4]

Stockpile goals established by the Federal Preparedness Agency and General Services Administration in late 1976 remained in effect. The goal for acid-grade fluorspar was set at 1,594,000 tons; for metallurgical-grade fluorspar, the goal was set at 1,914,000 tons. However, no acquisition plans for bringing the stockpile inventories up to goal levels were announced.

The Bureau of Mines conducted research at its Albany (Oregon) Metallurgy Research Center to develop production technology for the manufacture of synthetic fluorspar from waste fluosilicic acid, a byproduct of phosphoric acid production. The Bureau also test the effectiveness of synthetic fluorspar as a slag conditioner for electric and basic oxygen furnaces (BOF) in steelmaking and for cupola furnaces in ironmaking.

As in years past, a 22% depletion allowance was granted against Federal income tax, applied to the mining of domestic reserves, compared with a 14% allowance for foreign reserves.

DOMESTIC PRODUCTION

Shipments of finished fluorspar from domestic mining operations fell to 129,428 short tons in 1978 and 109,299 tons in 1979, which was the third consecutive year of declining shipments. Illinois was the leading producing State in 1978 and 1979 and accounted for almost 90% of all U.S. shipments. Shipments of acid-grade fluorspar in 1978 accounted for 58% of the U.S. total, nearly the same portion as in 1977. Due to the low number of acid-grade fluorspar producers operating in 1979, statistics on shipments and stocks were withheld to avoid revealing company proprietary data. In Illinois, the Ozark-Mahoning Co. operated four mines in Hardin County: The Knight, near Rosiclare, the Oxford No. 7 and Heavy Media Plant Shaft in the Cave-in-Rock area, and the Barnett, the only active fluorspar mine in Pope County. The

Table 1.—Salient fluorspar statistics[1]

		1975	1976	1977	1978	1979
United States:						
Production:						
Mine production	short tons	376,601	611,133	613,000	447,876	407,054
Material beneficiated	do	401,477	574,678	538,000	447,560	355,655
Material recovered	do	132,060	182,582	164,600	124,947	106,099
Finished (shipments)	do	139,913	188,270	169,489	129,428	109,299
Value f.o.b. mine	thousands	$14,888	$17,927	$16,479	$13,261	$12,162
Exports	short tons	1,384	4,923	6,642	8,267	14,454
Value	thousands	$234	$764	$975	$978	$1,339
Imports for consumption	short tons	1,050,448	895,254	971,355	916,703	1,021,085
Value[2]	thousands	$66,899	$64,881	$69,457	$67,569	$80,090
Consumption (reported)	short tons	1,244,988	1,273,498	1,162,336	1,203,448	1,135,451
Consumption (apparent)[3]	do	1,200,067	1,120,970	1,191,000	1,062,988	1,090,665
Stocks, Dec. 31:						
Domestic mines:						
Crude	do	57,833	88,905	204,466	121,329	163,619
Finished	do	11,386	14,870	12,243	4,322	5,400
Consumer	do	319,552	277,783	226,320	201,158	226,423
World: Production	do	4,985,568	[r]4,894,336	[r]5,146,217	5,282,279	5,359,882

[r] Revised.

[1] Does not include fluosilicic acid and imports of hydrofluoric acid and cryolite.

[2] F.o.b. foreign port in 1974; c.i.f. U.S. port, in 1975-78.

[3] Apparent consumption includes finished shipments plus imports, minus exports, minus consumer stocks increase.

company maintained a flotation mill and shipping facilities at Rosiclare and two heavy media plants, one at the Knight mine and the other at the Heavy Media Plant Shaft. Ozark began shaft sinking at its recently discovered Denton ore body in Hardin County and completed an 1,800-foot crosscut from its Barnett Mine to intersect more ore in the west vein area. Allied Chemical Corp. operated its Spivey mine and Minerva No. 1 mine, heavy media plant, and flotation mill in Hardin County. In September 1979, however, mining operations at Allied's mines were suspended pending the sale of these properties. Corporate decisions to divest Allied's interests in fluorspar mining prompted this suspension.

The only other active fluorspar producer in Illinois was the Hastie Trucking and Mining Co., which operated several open pits and a small heavy media concentrator at Spar Mountain near Cave-in-Rock. Hastie's primary products were a metallurgical gravel spar and construction aggregate. The company leased the former Victory mine property from Allied and was preparing to begin limited underground mine production there.

The only other active fluorspar operation in the East in 1978 was Frontier Spar Corp. of Salem, Ky., which temporarily shut down its Babb-Barnes mine and mill, but continued exploration in Livingstone County and further development at its Lasher-Robinson mine. Due to the decline in domestic demand and production, there were no shipments of fluorspar from Kentucky in 1979.

In the West, Tonto Mining and Milling Co. operated a flotation plant during the first half of 1978 at Tonto Basin, Ariz. Western Fluorspar Co. of Gila County, Ariz., had its ore custom milled by Tonto. In 1978 and 1979, J. Irving Crowell Jr. & Sons operated its Crowell Daisy mine in Beatty, Nev., selling the output locally. D & F Minerals Co. continued operation of its Paisano mine 80 miles south of Alpine, Tex.; production from this mine was used by a fluorspar briquet producer.

Although there had been no recorded fluorspar production in Tennessee since 1943, U.S. Borax and Chemical Corp. continued an active fluorspar exploration program near Sweetwater, Monroe County. Over the history of this program, more than 210 holes have been drilled, ranging in depth from 300 to 1,000 feet. A potential ore body of 26 million tons was indicated. By yearend 1979, a 490-foot exploration shaft was nearly completed. Borax plans to have a 1,700-foot exploration drift driven from the bottom of the shaft into the center of the ore body at the 500-foot level.

A study of domestic fluorspar briquet producers determined that in 1978, the total maximum annual capacity for domestic briquet producers was 802,000 tons (based on a 24 hour-per-day operation).[6] Actual reported production of briquets (made mostly from foreign ores) was about 200,000 tons in 1978. Historically, there has been intense competition for the major share of the steel fluxing market between the briquet producers and the gravel spar producers, who are principally located in Mexico. In 1978, briquets accounted for slightly less than half of the steel fluxing market.

Eleven plants recovered about 70,000 tons of H_2SiF_6 in 1978 as a byproduct of the wet-process manufacture of phosphoric acid from phosphate rock. About 78% of the total shipments of H_2SiF_6 were consumed to make aluminum chemicals, principally aluminum fluoride and synthetic cryolite; the remainder was used to make water fluoridation chemicals. The H_2SiF_6 shipments were the equivalent of about 80,000 tons of acid-grade fluorspar.

Table 2.—Shipments of finished fluorspar, by State

State	1978			1979		
	Quantity (short tons)	Value		Quantity (short tons)	Value	
		Total (thousands)	Average per ton		Total (thousands)	Average per ton
Illinois	115,859	$12,452	$107.48	W	W	$117.35
Other States[1]	13,569	809	59.62	W	W	83.70
Total	129,428	13,261	102.46	109,299	$12,162	111.28

W Withheld to avoid disclosing company proprietary data.
[1]Includes Arizona, Kentucky, Nevada, and Texas.

Table 3.—Shipments and mine stocks of finished fluorspar in the United States, by grade

Grade	1978				1979			
	Short tons	Value[1] (thousands)	Value per ton	Yearend stocks	Short tons	Value[1] (thousands)	Value per ton	Yearend stocks
Acid	[2]74,880	$8,270	$110.44	1,162	W	$10,512	$117.35	W
Metallurgical	54,548	4,991	91.50	3,160	W	1,650	83.71	W
Total	129,428	13,261	102.46	4,322	109,299	12,162	111.27	5,400

W Withheld to avoid disclosing company proprietary data.
[1]Total value as reported by mine production.
[2]Includes No. 1 ceramic grade.

CONSUMPTION AND USES

The hydrofluoric acid (HF) and steel industries accounted for about 52% and 45%, respectively, of the 1979 domestic fluorspar demand. The American Iron and Steel Institute (AISI) reported that total raw steel production was 137,031,000 tons in 1978 and 135,889,000 tons in 1979. Comparing the AISI data with fluorspar consumption data received by the Bureau of Mines from the steel producers, the calculated fluorspar consumption rate for the domestic steel industry in 1978 was 7.60 pounds per ton of steel produced, compared with 8.30 pounds per ton in 1979.

Eight companies operating eleven plants produced HF during 1979. Most production capacity was centered in the Texas-Louisiana area. Data collected by the U.S. Department of Commerce, Bureau of the Census, indicated that HF "produced and withdrawn from system" amounted to 183,000 short tons on an anhydrous basis in 1978 and 188,000 tons in 1979. Production of CFC's was a major use of HF, accounting for about 30% of the end use of this acid. According to data collected by the U.S. International Trade Commission on select CFC's, the 1979 production of F11 was 86,598 tons, the production of F12 was 142,996 tons, and the production of F22 was 105,919 tons. (F11, F12, and F22 are industry designations for various CFC's.) Compared to production in 1978, both F11 and F12, production decreased about 12%, but F22 production increased by 4%. The decline of fluorocarbons in aerosols was being offset by the use of CFC's in refrigerants, foam-blowing agents, and fluorinated solvents.

Producer	Plant location	Estimated capacity (tons per year)[1] 1978	Estimated capacity (tons per year)[1] 1979
Aluminum Co. of America	Point Comfort, Tex	55,000	55,000
Allied Chemical Corp	Baton Rouge, La. Geismar, La Nitro, W.Va Port Chicago, Calif	90,000	90,000
E. I. du Pont de Nemours & Co., Inc	Strang, Tex	75,000	75,000
Essex Chemical Corp	Paulsboro, N.J	11,000	11,000
Harshaw Chemical Co	Cleveland, Ohio	18,000	18,000
Kaiser Aluminum & Chemical Corp	Gramercy, La	50,000	--
Pennwalt Corp	Calvert City, Ky	25,000	25,000
Stauffer Chemical Co	Houston, Tex	6,000	--
Total		330,000	274,000

[1] Hydrogen fluoride gas generating capacity.

Sources: Chemical Marketing Reporter, Aug. 21, 1978 and Chemical Engr., Dec. 17, 1979.

Producer	Plant location	Estimated capacity (million of pounds per year)
Allied Chemical Corp	Baton Rouge, La Danville, Ill Elizabeth, N.J El Segundo, Calif	370
E. I. du Pont de Nemours & Co., Inc	Antioch, Calif Deepwater, N.J Louisville, Ky Montague, Mich Corpus Christi, Tex	500
Kaiser Aluminum & Chemical Corp	Gramercy, La	80
Pennwalt Corp	Calvert City, Ky	90
Racon Corp	Wichita, Kans	45
Total		1,085

Sources: Chemical Marketing Reporter, Aug. 7, 1978.

Production of fluorine chemicals used in the reduction of alumina to aluminum by the Hall process was another major end use of HF, with about 40% of the acid being consumed for this use. Six major companies, Aluminum Co. of America, Allied Chemical Corp., Kaiser Aluminum & Chemical Corp., Olin Corp., Stauffer Chemical Co., and Reynolds Metals Co., accounted for most of the domestic production of aluminum chemicals, namely aluminum fluoride and synthetic cryolite. Supplementing fluorspar as a domestic source of fluorine was H_2SiF_6, about 78% of which was used in the production of aluminum chemicals.

The author of a study of fluorine consumption trends in the aluminum industry foresaw a continued decrease in the amount of fluorine consumed per ton of primary aluminum produced. The main factor in this demand reduction was envisioned to be enhanced dry-fume recovery. U.S. consumption rates were anticipated to fall from a range of 46 to 58 pounds of fluorspar per ton of aluminum produced to the 24- to 36-pound range by the end of the century. Rest-of-world decreases in demand were expected to be in the 30% to 55% range.[6]

Also bearing on the fluorine consumption trends of the aluminum industry has been the recent trend to use lithium carbonate in aluminum potlines. The addition of this lithium compound has resulted in a 25% reduction of fluoride emissions and has also reduced power requirements by 10%.

Hydrofluoric acid was also required in the concentration of the uranium isotope U_{235} for use in nuclear energy. The U_3O_8 concentrate from the ore is first reacted with HF to produce UF_4, which is then converted to UF_6 through the addition of elemental fluorine. This process accounted for about 5% of HF demand. The fissionable isotope which is extracted for nuclear fuel accounts for only about 20% of the total uranium in the UF_6. A depleted product is left behind which—in addition to uranium metal values—contains significant values of fluorine that could be recycled in the further processing of uranium ore. This recycling could be a significant factor in the consumption of fluorine by the industry if increased uses are found for depleted uranium.

The remaining 25% of HF consumption was in the areas of petroleum alkylation, stainless steel pickling, and a host of minor uses including glass etching, oil and gas well treatment, dielectrics, decay preventatives in toothpastes and mouth washes, metallurgy, wood preservatives, electronics etching catalysts, and water fluoridation. (Fluosilicic acid has largely supplanted HF for use in water fluoridation.)

E. I. du Pont de Nemours & Co., Inc., completed the first half of a major capacity expansion to produce "Teflon" fluoropolymer resins and "Teflon" TFE (polytetrafluoroethylene) powder and aqueous dispersions. The expansion, which was scheduled for completion by mid-1979, was expected to boost fluoropolymer capacity by 50% and TFE capacity by 25%. Capacity increases were also planned for other "Teflon" products.[7]

Allied Chemical Corp. made its first bulk shipment of sulfur hexafluoride (SF_6) to a power substation of Ontario Hydro in Canada. The 20,000-pound shipment, supplied by Allied's Metropolis, Ill., plant, was to be used as a dielectric in extra-high-voltage (above 345 kv) switchgear. It was the first of several shipments to be supplied to the facility. The SF_6 gas was shipped to the site utilizing Allied's new fleet of tube trailer trucks designed expressly for such shipments and made to charge the gas directly to the switchgear. Allied was the world's largest producer of SF_6 gas and was planning a 50% capacity increase to be completed by late 1979.[8]

In the production of magnesium metal, it is common for the molten melt to react violently with atmospheric air to form an oxide coating on the surface. In the past, a salt-flux remedy has been used to create a nonreactive barrier, but the flux is very corrosive and presents other problems. However, researchers from the University of Michigan found that adding small amounts of SF_6 gas to the surface of molten magnesium prevented the melt from burning. This technique is expected to completely replace the salt-flux method.[9] Table 5 shows the reported consumption of metallurgical-grade fluorspar listed by end use and product form. This survey is new, and data are unavailable for years prior to 1979.

Table 4.—Reported domestic consumption of fluorspar, by end use and grade

(Short tons)

End use or product	Containing more than 97% CaF_2		Containing not more than 97% CaF_2		Total	
	1978	1979	1978	1979	1978	1979
Hydrofluoric acid	616,140	588,538	--	--	616,140	588,538
Glass and fiber glass	5,916	7,106	4,938	4,346	10,854	11,452
Enamel and pottery	118	302	754	1,130	872	1,432
Welding rod coatings	709	666	921	899	1,630	1,565
Primary aluminum and magnesium	1,032	843	137	234	1,169	1,077
Iron and steel castings	--	--	14,485	11,131	14,485	11,131
Open hearth furnaces	53	--	120,628	89,094	120,681	89,094
Basic oxygen furnaces	--	W	341,647	337,237	341,647	337,237
Electric furnaces	13,230	13,350	79,098	76,205	92,328	89,555
Other uses or products	1,744	1,529	1,898	2,841	3,642	4,370
Total	638,942	612,334	564,506	523,117	1,203,448	1,135,451
Stocks, Dec. 31, 1978	58,670	80,355	142,488	146,068	201,158	226,423

W Withheld to avoid disclosing company proprietary data.

Table 5.—Reported consumption of metallurgical-grade fluorspar[1] in 1979, by end use and form

(Short tons)

End use or product	Flotation concentrates	Lump or gravel	Briquets or pellets
Chemicals and allied products:			
Hydrofluoric acid	--	--	--
Welding fluxes	777	122	--
Glass, ceramic, bricks:			
Glass	4,335	W	--
Other glass, clay products	1,130	--	--
Primary metals:			
Steel mills:			
Open hearth furnaces	W	65,669	23,419
Basic oxygen furnaces	2,198	162,336	172,703
Electric furnaces	1,191	69,297	5,717
Other steel furnaces	--	--	--
Iron and steel foundries	312	8,850	1,969
Aluminum	W	W	--
Magnesium	W	--	--
Other primary metals	--	--	--
Other identified end uses	253	2,253	586
Total	10,196	308,527	204,394

W Withheld to avoid disclosing company proprietary data; included with "Other identified end uses."

[1] Containing not more than 97% CaF_2.

Table 6.—Fluorspar (domestic and foreign) consumed in the United States, by State

(Short tons)

State	1978	1979
Alabama, Kentucky, Tennessee	83,377	91,441
Arizona, Colorado, Utah	31,372	34,196
Arkansas, Kansas, Louisiana, Missouri	247,775	203,398
California	36,433	30,727
Connecticut, Massachusetts, New York, Rhode Island	31,174	22,948
Illinois	48,519	51,672
Indiana	75,244	61,837
Iowa and Wisconsin	915	1,607
Michigan	41,933	46,885
New Jersey	25,234	19,731
Ohio	137,041	136,188
Oregon and Washington	1,053	982
Pennsylvania	122,247	101,950
Texas	238,580	252,951
West Virginia	46,831	45,340
Other States[1]	35,720	34,197
Total	1,203,448	1,135,451

[1] Includes Delaware, Georgia, Maryland, North Carolina, Oklahoma, and Virginia.

STOCKS

The 1979 yearend mine stocks of finished fluorspar totaled 5,400 tons, reflecting a 25% increase from the previous year's stocks. The 1978 fluorspar stocks were reduced from the previous year's levels to 4,322 tons. Consumer stocks increased from 201,158 tons in 1978 to 226,423 tons in 1979. Government stockpiles of strategic and critical fluorspar materials remained unchanged from 1977 and included 895,984 short tons of acid-grade fluorspar (of which 630 tons were considered nonstockpile grade) and 411,738 tons of metallurgical-grade fluorspar (of which 116,863 tons were of nonstockpile grade).

FOREIGN TRADE

A total of 14,454 tons of domestic fluorspar was exported in 1979; most of this total went to Canada, as a result of mine closures in that country.

Total U.S. imports of fluorspar for 1979 rose 11% over 1978 import levels. Mexico, the largest exporter to the United States, supplied 66% of the U.S. import total, or

678,057 tons. The Republic of South Africa supplied 24%, or 243,681 tons, and Italy supplied 4% of the total, or 36,203 tons. Of the total imports, 63%, or 639,001 tons, was acid grade, compared with 64% in 1978; the remaining 382,084 tons was metallurgical grade. U.S. imports of cryolite in 1979 declined from the 1978 level to 13,692 tons, but were nonetheless up 16% from 1977 levels. Canada provided 39% of the cryolite imports, with the Federal Republic of Germany, Denmark, and Japan supplying most of the remainder. Imports of HF (70% basis) were 14% higher than in 1978. Mexico, the largest supplier of the acid, supplied 58% of the total and was followed by Canada and Japan, which supplied nearly all the remainder.

Table 7.—U.S. exports of fluorspar

Countries	1978		1979	
	Quantity (short tons)	Value	Quantity (short tons)	Value
Australia	91	$9,028	--	--
Belgium	21	3,555	--	--
Canada	7,970	810,019	13,941	$1,280,788
Chile	--	--	38	3,849
Colombia	1	3,535	--	--
Dominican Republic	60	11,358	190	40,621
Ghana	20	86,600	--	--
Israel	--	--	12	1,212
Italy	20	678	--	--
Japan	5	528	39	3,900
Malaysia	--	--	13	1,270
Mexico	--	--	18	1,811
Panama	5	1,000	--	--
South Africa, Republic of	--	--	21	5,760
United Kingdom	28	41,465	113	11,295
Venezuela	46	9,794	69	8,938
Total	8,267	977,560	14,454	1,389,444

Table 8.—U.S. imports for consumption of fluorspar, by country and customs district

Country and customs district	1978			1979		
	Quantity (short tons)	Value (thousands)		Quantity (short tons)	Value (thousands)	
		Customs	C.i.f.		Customs	C.i.f.
CONTAINING MORE THAN 97% CALCIUM FLUORIDE						
Canada:						
El Paso	--	--	--	1,029	52	85
Laredo	--	--	--	78	6	6
Total	--	--	--	1,107	58	91
Greenland: El Paso	--	--	--	77	6	6
Italy: Galveston	43,679	3,267	3,718	36,203	2,920	3,443
Kenya:						
Detroit	17,320	1,221	1,531	11,168	483	900
Houston	--	--	--	15,681	908	1,139
Total	17,320	1,221	1,531	26,849	1,391	2,039
Mexico:						
Detroit	588	64	64	214	9	11
El Paso	104,860	5,594	8,657	93,074	4,993	7,707
Laredo	215,738	16,369	16,606	222,514	17,450	17,504
Los Angeles	--	--	--	77	6	6
Pembina	--	--	--	77	6	6
Philadelphia	--	--	--	12,932	1,068	1,129
San Diego	--	--	--	77	6	6
San Francisco	--	--	--	77	6	6
Total	321,186	22,027	25,327	329,042	23,544	26,375
Morocco: Philadelphia	5,770	393	466	--	--	--
South Africa, Republic of:						
Detroit	--	--	--	12,995	743	1,060
Galveston	--	--	--	7,388	509	714
Houston	--	--	--	16,933	1,173	1,554
Laredo	19,570	1,163	1,476	9,868	590	772
New Orleans	140,180	9,156	11,614	156,078	10,866	14,987
Philadelphia	--	--	--	8,140	563	597
Total	159,750	10,319	13,090	211,402	14,444	19,684
Spain:						
Cleveland	25,228	1,692	2,170	23,411	2,108	2,425
Galveston	4,939	358	415	--	--	--
Philadelphia	9,555	721	843	10,910	871	921
Total	39,722	2,771	3,428	34,321	2,979	3,346
Grand total	587,427	39,998	47,560	639,001	45,342	54,984
CONTAINING NOT MORE THAN 97% CALCIUM FLUORIDE						
Canada:						
El Paso	--	--	--	600	12	12
Laredo	--	--	--	190	13	13
Total	--	--	--	790	25	25
Mexico:						
Baltimore	4,645	304	315	38,834	2,397	2,918
Buffalo	15,913	928	1,038	16,624	1,023	1,231
El Paso	49,356	1,622	1,622	43,248	1,399	1,399
Galveston	--	--	--	128	8	8
Laredo	158,870	9,440	9,441	175,137	11,488	11,546
New Orleans	13,201	785	861	65,501	4,266	4,819
Philadelphia	4,778	324	390	9,548	638	769
Total	246,763	13,403	13,667	349,015	21,219	22,690
South Africa, Republic of:						
Chicago	2,464	136	166	1,311	80	154
New Orleans	40,257	2,299	2,929	30,968	1,768	2,237
Philadelphia	6,778	464	589	--	--	--
Total	49,499	2,899	3,684	32,279	1,848	2,391
Spain: Baltimore	33,014	2,515	2,658	--	--	--
Grand total	329,276	18,817	20,009	382,084	23,092	25,106

Table 9.—U.S. imports for consumption of 70% hydrofluoric acid

Country	1978 Quantity (short tons)	1978 Value (thousands)	1979 Quantity (short tons)	1979 Value (thousands)
Canada	34,444	$16,923	39,453	$22,563
France	--	--	137	196
Germany, Federal Republic of	([1])	1	266	398
Japan	--	--	1,664	1,538
Mexico	53,912	30,610	58,597	43,539
Netherlands	--	--	41	60
Sweden	--	--	22	5
Switzerland	--	--	13	17
United Kingdom	709	414	963	1,208
Total	89,065	47,948	101,156	69,521

[1] Less than 1/2 unit.

Table 10.—U.S. imports for consumption of cryolite[1]

Country	1978 Quantity (short tons)	1978 Value, c.i.f. (thousands)	1979 Quantity (short tons)	1979 Value, c.i.f. (thousands)
Canada	3,067	$1,250	5,320	$2,179
China, mainland	476	193	590	257
Denmark	9,530	4,959	2,436	1,575
Germany, Federal Republic of	174	111	2,954	1,716
Greenland	632	325	160	101
Japan	5,510	2,782	2,173	1,318
Netherlands	61	39	58	49
Switzerland	2	1	1	([2])
Total	19,452	9,660	13,692	7,195

[1] Only the material from Denmark is natural cryolite; all other material is synthetic.
[2] Less than 1/2 unit.

PRICES

Average values for fluorspar shipments in 1979 as reported by domestic mines advanced about 27% for acid-grade material and declined 67% for metallurgical-grade shipments. Yearend quotations by the Engineering and Mining Journal are presented in table 11. Mexican prices remained stable during 1979 for the third consecutive year, but a 6% across-the-board price increase was announced that would take effect on January 1, 1979. European and South African term contracts for acid-grade material showed some upward pressure but remained relatively unchanged from prices in 1976.

Table 11.—Prices of domestic and imported fluorspar

(Dollars per short ton)

	1978	1979
Domestic, f.o.b. Illinois-Kentucky:		
Metallurgical: 70% effective CaF_2 briquets	91	91
Ceramic, variable calcite and silica:		
88% to 90% CaF_2	90-100	100
95% to 96% CaF_2	95-109	109
97% CaF_2	100-115	121.50
Acid, dry basis, 97% CaF_2:		
Carloads	111-115	117
88% effective CaF_2 briquets	111	111
European and South African:[1] Acid, term contracts	97-105	130-145
Mexican:[2]		
Metallurgical:		
70% effective CaF_2, f.o.b. vessel, Tampico	65.52	69.45
70% effective CaF_2, f.o.b. cars, Mexican border	62.92	66.70
Acid, bulk: 97% +, Mexican border	79.38	84.14

[1] C.i.f. east coast, Great Lakes, and Gulf ports.
[2] U.S. import duty, insurance, and freight not included.

Source: Engineering and Mining Journal, December 1978 and 1979.

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WORLD REVIEW

World production of fluorspar increased 2% in 1979 to about 5.4 million tons. Mexico remained the leading producer, with 20% of the world production, and was followed by the U.S.S.R., Mongolia, the Republic of South Africa, Spain, mainland China, and France (in order of volume).

According to a report issued by the Minerals Bureau of the South African Department of Mines, total world demand for fluorspar was projected to increase at a 7.4% annual rate to 4.5 million short tons of fluorspar concentrates by 1980. Demand in developed countries was forecast to grow at a lesser rate, [illegible].2% per year to 2.9 million tons by 1980. Total world demand for fluorspar used by the steel industry was expected to increase to 62% of the total demand, and demand for aluminum production was expected to account for 18% of the total. Consumption of fluorspar in the fluorochemical industries was expected to decrease to 20% of the total demand.[10]

According to a study carried out for the U.S. Manufacturing Chemists Association (MCA), free world production of F11 and F12, the CFC's most commonly used for propellents, decreased 6.5% from 1976 to 1977 and was [illegible]% less than the 1.6 billion pounds produced in 1973. MCA was conducting a research program to monitor worldwide effects, if any, of CFC's on atmospheric ozone.[11]

The West German Ministry of the Interior sponsored a conference in December 1979 which concluded that although the role of CFC's in the depletion of atmospheric ozone is uncertain, steps to reduce consumption on a voluntary basis should be taken on the assumption that atmospheric ozone has already been reduced by 15%. The conference also recommended that each country report annual consumption to the United Nations Environment Program. Studies in the United States by the National Academy of Sciences and the National Oceanic and Atmospheric Administration (NOAA) concluded that ozone depletion in the atmosphere would produce harmful worldwide health and environmental hazards. CFC's are also believed to last at least 30 years in the lower atmosphere, which is longer than was previously believed.[12]

Brazil.—Sagging domestic fluorspar production forced Cia. Siderurgica Paulista to purchase about 2,700 tons of Mexican fluorspar to maintain supplies at its steel plant.[13]

Canada.—Canada's only active fluorspar mine, the Newfoundland Fluorspar Works of the Aluminum Co. of Canada, Ltd., (Alcan) shut down all operations in February 1978 (mining ceased in late 1977). Alcan found that it was more economical to import its fluorspar needs, although consultants from the United Kingdom determined that the Alcan deposit could be mined more economically than it had been if only the Trefare and Blue Beach veins were worked and if new mining and concentration practices were introduced.[14]

In British Columbia, Rexspar Minerals and Chemicals Company was reevaluating its uranium-fluorspar property at Birch Island. Complex metallurgical problems and environmental considerations had been posing obstacles for the proposed 7,000-ton-per-week operation.[15]

China, mainland.—Members of a Japanese trade mission made a contract with mainland China to buy about 45 thousand tons of metallurgical-grade fluorspar to be shipped over a 10-month period starting in June 1978.[16]

Italy.—A fluorspar deposit in Pianciano, 55 miles northwest of Rome, received a favorable appraisal for further development. Soricon SpA, a wholly owned subsidiary of Southland Mining, Ltd., an Australian firm, had more than 5,000 acres under lease that contained 7.1 million tons of ore averaging 43.9% fluorspar. Fluorite occurred in a bedded deposit of pyroclastic lacustrine muds and was suitable for surface mining. The ore occurrence was subdivided into sandy and clayey fractions. In both fractions, most of the fluorite occurred as particles less than 2 micrometers in size. The clayey ore averaged 55.7% fluorspar, and the sandy ore averaged 20.7%. The deposit had been known for at least 20 years, but lack of a suitable beneficiation process had precluded development. A new process was claimed to effect a 75% recovery on the Pianciano ores.[17]

Mexico.—Instituto Mexicano de la Fluorita, A.C., representing 120 fluorite producers in Mexico, recommended that Mexican fluorspar prices remain stable throughout 1978. The Institute reported that total sales of Mexican fluorspar for 1978 amounted to 1,167,023 tons, which was 18% higher than the previous year's sales; 1978 was the highest sales year since 1974. Sales to U.S. consumers accounted for 50% of the total. Sales to Mexican consumers were 298,000 tons, up 18% from 1977.

E. I. du Pont de Nemours & Co., Inc., announced that it would sell 51% of the stock in its LaDominicia fluorspar mine to Mexican investors. The operation—one of the seven largest fluorspar mines in Mexico—would thus become "Mexicanized," qualifying it to obtain new mining concessions under the Mexican mining law.[18]

A paper summarizing fluorspar developments in Mexico was presented. It was explained that there are two fluorspar belts in Mexico. The eastern belt extends from the Encantada district around Muzquiz, Coahuila, southward to San Luis Potosi in central Mexico. The western belt extends from the Parral mining area in Chihuahua southward to Zacatecas. Mexico has abundant reserves of low-silica, high-CaF_2 material and is the only known significant source of natural-lump metallurgical-grade fluorspar in the western world. Because Mexican fluorspar is generally high grade, it has been possible for Mexican producers to be flexible in providing whatever grade of product is required by the market. In 1978, about 140 fluorspar mines were operating in Mexico, and 9 of these mines accounted for 85% of the total production. The Las Cuevas mine in San Luis Potosi was the largest fluorspar mine in the world. Mines that produced only fluorspar accounted for 83% of the country's installed capacity; the remainder of the capacity was accounted for by fluorspar byproduct production from silver and lead mines. Total Mexican fluorspar capacity was pegged at 1.4 million tons. Present fluorspar mines were estimated to have a total reserve of 36 million tons of fluorspar with a CaF_2 content greater than 60%.[19]

Mongolia.—An expansion was underway to double fluorspar output by 1980. Plans were for this fluorspar to be consumed by the Soviet steel industry.

Pakistan.—Commercial extraction of fluorspar deposits began at Koh-e-Dilland in Kalat District, Baluchistan. Official estimates of reserves were about 85,000 tons of CaF_2. An annual production rate of about 4,500 tons of metallurgical-grade material was anticipated, and it was expected that 80% of this production would be used by the Pakistan Steel Mills Corp., with the remainder intended for local foundries.[20]

South Africa, Republic of.—Production of fluorspar is estimated to have reached an alltime high of 497,265 tons, which was 15% higher than the 1978 total. The South African Minerals Bureau of the Department of Mines predicted that the Republic of South Africa would become the world's major supplier of fluorspar from 1985 onwards.[21] Reserve figures were revised upward to about 170 million tons (15% to 30% CaF_2, averaging 25%), which was 60% more than the 1976 estimates.[22] This reevaluation was based partly on improved beneficiation techniques that allow for increased recovery.

The largest fluorspar mines in the Republic of South Africa were all open-cast mines located in the northeastern part of the country. The major South African producers included Buffalo Fluorspar (Pty), Ltd. (formerly owned by United States Steel International and sold to Philipp Bros.); Chemspar, Ltd. (owned by Phelps Dodge of Africa, Ltd.); Ruigtepoort Fluorspar Mines (Pty), Ltd.; and Vergenoeg Mining Co. (Pty), Ltd., (owned by Bayer A.G.).

The Unit for Futures Research at the Republic of South Africa's Stellenbosch University forecast that 1.2 million tons of fluorspar would be mined in the Republic of South Africa in 2000.

Spain.—Fluoruros, S.A., which is 90% owned by Bethlehem Steel Co., was the owner of large fluorspar processing plants fed partly by its own small mines but fed mostly from material provided by Minas de Villabona, S.A., which had only small processing plants of its own. Fluoruros had cash flow problems due to increasing expenses and depressed fluorspar prices and had incurred a 45-million-peseta debt with Villabona. Instead of extending further credit, Villabona stopped shipments of ore at yearend and curtailed its own operations. Fluoruros, with its 280,000-ton-per-year operation, accounted for most of Spain's fluorspar exports.[23]

Thailand.—Production of fluorspar in 1979 dropped 4% to an estimated 244,000 tons. Since the world recession of 1973-74, Thailand's fluorspar production was halved, and the number of fluorspar mines was reduced from 81 to 34. Japan, although still Thailand's largest fluorspar customer, turned increasingly to mainland China and the Republic of South Africa for its purchases of metallurgical fluorspar. Of all Japanese fluorspar imports, 29% came from Thailand in 1978, compared with 37% in 1977.

In order to offset the loss of fluorspar markets, Thailand's Board of Investment recommended the establishment of a briquet plant, HF facility, and a plant to produce synthetic cryolite. Use of indigenous mineral deposits to produce refined products was envisioned as a way to lessen the balance-of-trade deficit and attract manufacturing operations.[24]

United Kingdom.—Dresser Minerals International had purchased a fluorspar mine and mill in 1977 that was formerly owned by the Italian firm G.E. Giuline. The mill was located in Derbyshire, but plans to mine at Youlegreave in Peak District National Park met opposition from the Park Planning Board. A permit to mine was denied in July 1978 because Dresser did not provide reclamation plans which were satisfactory to the Board. Later in the year an agreement was worked out whereby Dresser would put up a £ 175,000 bond guaranteeing full restoration of the 10-acre site. Dresser planned to mine nearly 11 million tons of ore over the next 5 years from a seam about 40 feet wide and 100 feet deep.[25]

In Frosterly, County Durham, a fluorspar processing plant was completed in November 1978. The plant, owned by Swiss Aluminum Mining (U.K.) (Samuk), included heavy media and flotation units having a designed capacity of 135 to 180 thousand tons of ore per year yielding 45 to 90 thousand tons of finished product. The new plant replaced an old facility at Rockhope (that was formerly part of the Weardale Lead Co.) and will provide Samuk with a five-fold capacity increase. Samuk was formed in 1971 to develop fluorspar mining operations in County Durham. This extensive mineral district was first mined for lead as early as ancient Roman times, and some of the mill feed would be expected to include old lead-mine tailings. Samuk acquired five mines and mineral rights in an area larger than 115 square miles; the area is a part of the north Pennine ore field.[26]

Imperial Smelting Corporation, (a Rio-Tinto Zinc Corp. Ltd. subsidiary) awarded a contract to Matthew Hall Norcain to build an aromatic fluorine-compound plant at Avonmouth. The 450-ton-per-year plant was to be the first of its kind in the United Kingdom and would make ISC a leading world supplier of aromatic fluorine compounds. Among the compounds planned for production was 2,4 difluoroaniline, an intermediate used in making difluisil. Difluisil is the analgesic ingredient used to make Dolobid, a new aspirin substitute.[27]

Table 12.—Fluorspar: World production, by country

(Short tons)

Country[1] and grade[2]	1976	1977	1978[p]	1979[e]
North America:				
Canada, acid grade[e] [3]	[r]70,500	[r]65,600	--	--
Mexico:[4]				
Acid grade	320,134	460,344	540,259	541,600
Ceramic grade	28,107	36,124	49,725	49,800
Metallurgical grade	411,798	496,483	577,040	578,000
Unspecified	346,297	59,826	-109,044	-108,900
Total	1,106,336	1,052,777	1,057,980	1,060,500
United States (shipments):				
Acid grade	116,300	100,605	74,880	W
Metallurgical grade	71,970	68,884	54,548	W
Total	188,270	169,489	129,428	109,299
South America:				
Argentina:				
Acid grade[e]	13,253	[r]14,482	13,600	13,500
Metallurgical grade[e]	30,924	[r]33,790	31,600	33,000
Total	44,177	48,272	[e]45,200	46,500
Brazil:[5]				
Direct shipping ore, grade unspecified (sales)	61	14,509	NA	NA
Beneficiated product (output):				
Acid grade	34,287	30,071	67,610	NA
Ceramic grade		524		NA
Metallurgical grade		28,359		NA
Total	34,348	73,463	67,610	77,000
Uruguay, grade unspecified	55	83	[e]90	85
Europe:				
Czechoslovakia:[e] [3]				
Acid grade	[r]51,500	[r]53,000	53,000	53,000
Metallurgical grade	[r]51,500	[r]53,000	53,000	53,000
Total	[r]103,000	[r]106,000	106,000	106,000
France:[e] [6]				
Acid and ceramic grade	[r]208,000	207,000	NA	NA
Metallurgical grade	[r]129,000	105,000	NA	NA
Total	[r]337,000	312,000	347,000	347,000
German Democratic Republic:[e] [3]				
Acid grade	25,000	27,600	27,600	27,600
Metallurgical grade	75,000	82,400	82,400	82,400
Total	100,000	110,000	110,000	110,000
Germany, Federal Republic of (marketable):[3]				
Acid grade[e]	63,701	83,086	NA	NA
Metallurgical grade[e]	7,078	9,232	NA	NA
Total	70,779	92,318	83,491	94,000
Greece, grade unspecified	[e]1,100	551	672	650
Italy:				
Acid grade	[r]193,192	158,000	143,320	140,000
Ceramic grade	9,205	14,544	14,328	14,300
Metallurgical grade	29,983	32,209	31,085	30,900
Total	[r]232,380	204,753	188,733	185,200
Romania, metallurgical grade[e] [3]	17,000	22,000	22,000	22,000
Spain:				
Acid grade	[r]244,688	[r]233,497	218,847	232,000
Metallurgical grade	[r]71,293	[r]108,727	219,360	220,000
Total	[r]315,981	[r]342,224	438,207	452,000
Sweden:[5]				
Acid grade[e]	2,015	[r]1,464	--	--
Metallurgical grade[e]	1,649	[r]1,197	--	--
Total	3,664	2,661	--	--

See footnotes at end of table.

Table 12.—Fluorspar: World production, by country —Continued

(Short tons)

Country[1] and grade[2]	1976	1977	1978[p]	1979[e]
Europe: —Continued				
U.S.S.R.:[e] [3]				
Acid grade	260,000	265,000	270,000	275,000
Metallurgical grade[6]	280,000	287,000	292,000	298,000
Total	540,000	552,000	562,000	573,000
United Kingdom:[7]				
Acid grade	[r]147,710	[r]115,743	NA	NA
Metallurgical grade	[r]31,967	[r]25,353	NA	NA
Unspecified	[r]59,524	[r]72,311	NA	NA
Total	[r]239,201	[r]231,407	209,900	210,000
Africa:				
Egypt, grade unspecified	1,716	1,548	2,464	2,700
Kenya:				
Acid grade	NA	116,575	103,278	98,000
Metallurgical grade	NA	20,111	14,189	12,000
Total	82,703	136,686	117,467	110,000
Morocco, acid grade	56,714	44,100	59,700	65,000
Rhodesia, Southern, metallurgical grade[e] [3]	220	220	220	220
South Africa, Republic of:				
Acid grade	232,449	258,656	328,038	426,930
Ceramic grade	43,543	72,378	16,432	9,344
Metallurgical grade	44,469	55,523	89,042	60,991
Total	320,461	386,557	433,512	497,265
Tunisia, acid grade	[r]38,004	31,800	33,000	34,000
Zambia, grade unspecified	3	[e]11	84	88
Asia:				
China, mainland, metallurgical grade[e] [3]	385,000	[r]440,000	440,000	440,000
India:				
Acid grade	[r]10,702	9,997	10,594	12,000
Metallurgical grade	4,708	6,768	4,729	5,700
Total	[r]15,410	16,765	15,323	17,700
Korea, North, metallurgical grade[e] [3]	33,000	44,000	44,000	44,000
Korea, Republic of, metallurgical grade	22,344	14,309	12,581	10,000
Mongolia, metallurgical grade[3]	[e]333,000	369,200	501,400	500,000
Pakistan, grade unspecified	11	--	369	275
Thailand:[8]				
Acid grade	[r]58,777	60,435	60,627	43,000
Metallurgical grade	141,679	213,093	193,490	201,000
Total	[r]200,456	273,528	254,117	244,000
Turkey, metallurgical grade	1,413	1,886	1,381	1,400
Grand total	[r]4,894,336	[r]5,146,217	5,282,279	5,359,882

[e]Estimate. [p]Preliminary. [r]Revised. NA Not available. W Withheld to avoid disclosing company proprietary data.

[1] In addition to the countries listed, Bulgaria is believed to have produced fluorspar, but production is not officially reported, and available information is inadequate for the formulation of reliable estimates of output levels.

[2] An effort has been made to subdivide production of all countries by grade (acid, ceramic, and/or metallurgical). Where this information is available in official reports of the subject country, the data has been entered without qualifying notes; where a secondary source has been used to subdivide production by grade, the source for the basis of this subdivision has been identified by footnote. Where no basis for subdivision is available, the entry has been identified with the notation "grade unspecified."

[3] Information on grade obtained from Bundesanstalt Für Bodenforschung Hannover and Deutsches Institut Für Wirtschaftsforschung Berlin. Untersuchungen über Angebot and Nachfrage Mineralischer Rohstoffe IV. Flusspat, March 1974, p. 39.

[4] Totals for all years are reported production for all grades of fluorspar. Data by grade are exports and local sales as listed by Instituto Mexicano de la Fluorita (Mexican Fluorspar Institute). Metallurgical grade fluorspar includes material listed as submetallurgical in nature, while unspecified material represents the difference between reported exports and production and, as such, presumably is indicative of additions to or deletions from stocks.

[5] Official Brazilian sources list crude ore mined as follows in short tons: 1976-54,448; 1977-171,916; 1978-184,500 (estimated); 1979-NA.

[6] Data for 1976-77 are marketed production estimated from domestic consumption and trade data; it does not take into account changes in stocks. Total run-of-mine production (direct-shipping plus ore destined for concentration was as follows in short tons: 1976-744,000; 1977-586,000; 1978-584,000; 1979-584,000).

[7] Includes material recovered from lead-zinc mine dumps.

[8] Acid-grade material listed for Thailand is beneficiated product resulting from processing of reported low-grade material; metallurgical-grade material is run-of-mine material reported under the term "high grade." Recorded production of low-grade material was as follows in short tons: 1976-79,184; 1977-51,246; 1978-92,875; 1979-69,000 (estimated).

TECHNOLOGY

The role of CFC's in the depletion of stratospheric ozone continued to be a subject of controversy. One group at the Federal Republic of Germany's Institute for Ecological Chemistry at Munich found that CFC's decompose in the lower atmosphere.[28]

The effectiveness of satellite measurement of stratospheric ozone and aerosols was a subject of a study commissioned by the National Aeronautics and Space Administration.[29] The Manufacturing Chemists Association set up a network of four CFC monitoring stations located in Ireland, Barbados, American Samoa, and Tasmania. Data from the stations is expected to help determine if there is any accumulation or natural sinks for CFC's in the lower atmosphere.[30]

Some measurements have detected an increase in stratospheric ozone. It was proposed that increased atmospheric carbon dioxide levels may be linked to the increase in ozone.[31]

A researcher at Rochester University determined that water supply fluoridation may be a factor in the reduction of heart disease. This determination may support the theory that fluoride inhibits calcification, which causes hardening of the arteries around the heart.[32]

E. I. du Pont de Nemours & Co., Inc., and Imperial Chemical Industries, Ltd., conducted further testing of CFC F22 after preliminary tests had indicated the material was weakly tetratogenic in rats. Exposure to F22 at the Occupational Safety and Health Administration maximum concentration standard of 1,000 parts per million was found to have no statistically significant ill effects. Du Pont continued to recommend that use of F22 be limited until further long-term tests are completed.[33]

A study of fluoride emissions from gypsum-disposal and cooling-water ponds of phosphoric acid manufacturing plants was released. It was concluded that the most promising method of fluoride emissions control was to recover H_2SiF_6 and segregate cooling-water from gypsum-pond waters.[34]

The National Institute for Dental Research recommended that children start regular programs to rinse with fluoride preparations for tooth decay prevention. A 3-year project using fluoride preparations and focusing on elementary school children found that tooth decay could be reduced by an average of 35%.[35]

A patent was granted for a method of detecting subsurface deposits of fluorspar. The method uses a combination of magnetic and gravitational techniques.[36] A patent was also granted for a new method of beneficiating fluorspar and other nonsulfide ores by froth flotation. The collector used in the process is a partial ester of polycarboxlic acid said to enhance recovery and at the same time permit recycling of process streams.[37] Another patent was granted for a method using fluorine compounds to recover titania from ilmenite. The ore is first digested with HF, and the solution is then treated with ammonium fluoride and hydroxide in order to precipitate an iron-ammonium complex.[38] A Canadian patent was awarded for a method of detecting fluorspar in an ore or in rock samples. The chemical colorimetric test is particularly suitable for diamond-drill cores.[39] A history of development, present processes, and uses for fluoroaromatics was discussed.[40]

Apart from a growing use of SF_6 as a dielectric, SF_6 was noted for its utility as a leak detector in water mains. The nontoxic, nonpolluting gas is injecfed into the main at a concentration of about 6 parts per million. Shallow holes about 6 inches deep are made along the pipeline route, and each one is checked for the presence of SF_6 gas with a commercially available detector. The use of SF_6 to replace tracer dyes for river monitoring studies was also contemplated[41]

An announcement was made that a 125-ton-per day demonstration plant would be constructed, using fluorocarbons as the liquid medium in a flotation process to remove sulfur and other impurities from coal. The project was to be funded by the American Electric Power Institute.[42] A multiclient study conducted by Batelle Columbus Laboratories concluded that fluoroplastic-lined steel products would soon find much wider application in the chemical process industries because of the plastics' high heat stability and low reactivity. The fluoroplastics can be applied directly to coil steel, making direct forming of a precoated product possible.[43]

Developments in fluorinated coatings for ships were reported. These new coatings provided a tough, durable membrane and were heavily fluorinated, highly crosslinked materials of the epoxy and polyurethane classes. The coatings hinder water penetration because they are not readily wettable and the molecular absorption of water into the film is relatively small.[44]

An important new material for solar photovoltaic cells promised to cut the cost and improve the efficiency of these devices. Developed by Energy Conversion Devices, Inc., of Troy, Mich., the main structure of the cell consisted of doped and undoped layers of amorphous silicon and fluorine-compounds, which together act as a semiconductor. Such layers could also be used for other semiconducting applications.[45] [46]

Dolibid, an aspirin substitute containing fluorine compounds, after being discovered in the United States, was test marketed in the United Kingdom in April 1978.[47]

Foote Mineral Co., of Jenkintown, Pa., announced its new lithia-containing flux for use in steelmaking. The product, called Footespar, is a metallurgical fluorspar substitute.

New geologic data on New Mexico's fluorspar districts and specific deposits, along with developments and discoveries since 1966, was presented in a publication by the New Mexico Bureau of Mines and Mineral Resources.[48]

A report on the Bayhorse fluorite deposit in Custer County, Idaho, was published. The deposit had a measured reserve of 73.2 million short tons grading 36% CaF_2. The deposit was formed as an open space, filling in collapse breccia features of the Ordovician Bayhorse Dolomite. Mineralization was probably related to the Eocene Challis Volcanic Series.[49]

An artificial blood substitute called Fluosol was sucessfully used in life-saving blood transfusions. The fluorine-based compound could prove invaluable for disaster victims, battlefield casualties, patients with rare blood types, and patients whose religious beliefs prohibit normal blood transfusions.[50]

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Gallium

By Benjamin Petkof[1]

The domestic gallium industry continued to provide a significant portion of U.S. demand although gallium imports increased in 1978 and 1979. Data on world production and consumption were not available. Gallium was consumed for the production of various gallium compounds used to produce electronic devices.

Legislation and Government Programs.—New tariff rates for imported gallium metal and compounds resulted from the 1979 Tokyo round of tariff negotiations giving most nations "most-favored nation" status. The tariffs for these nations will decline annually, in stages, beginning January 1, 1980 and ending January 1, 1987.

Table 1.—Salient gallium statistics in the United States

(Kilograms)

	1975	1976	1977	1978	1979
Production	W	W	NA	NA	NA
Imports for consumption	6,830	4,920	2,884	3,721	6,401
Consumption	7,498	8,880	8,789	8,908	9,461
Price per kilogram	$750-$800	$750-$800	$500-$600	$500-$600	$510

NA Not available. W Withheld to avoid disclosing company proprietary data.

DOMESTIC PRODUCTION

The Aluminum Co. of America, using proprietary technology at its Bauxite, Ark., alumina plant, recovered gallium as a coproduct from residues of its alumina production process. Eagle-Picher Industries, Inc., produced gallium metal, oxide, and trichloride from zinc production residues at its Quapaw, Okla., facility. Production data are not available. Based on consumption and import data, total domestic output was thought to have declined in 1978 and 1979.

CONSUMPTION

Gallium consumption was strong in 1978 and 1979 and was above that of 1977. The electronics industry had the greatest demand for high-purity material to fabricate light-emitting diodes, semiconductors, and other electronic devices. Small quantities of metal were used to prepare specialty alloys and in research and development. Gallium oxide was used for the preparation of phosphors.

General acceptance by the public of various electronic devices that use gallium-based components helped sustain gallium demand. Continued interest in the development of gallium-based direct solar energy-conversion cells for the production of electricity and further development of fiberoptic light-transmission cables actuated by gallium-based light-emitting diodes, may stimulate demand for gallium and gallium compounds in the near future.

Table 2.—Consumption of gallium, by end use

(Kilograms)

End use	1977	1978	1979
Alloys[1]	4	5	5
Electronics[2]	7,965	8,305	8,782
Research and development	763	584	617
Unspecified uses	57	14	57
Total	8,789	8,908	9,461

[1] Specialty alloys.

[2] Light-emitting diodes, semiconductors, and other electronic devices.

Table 3.—Stocks, receipts, and consumption of gallium[1]

(Kilograms)

Purity	Beginning stocks[2]	Receipts	Consumption	Ending stocks[2]
1978:				
97.0%-99.9%	8	104	4	108
99.99%	7	20	13	14
99.999%	4	60	59	5
99.9999%-99.99999%	1,525	9,169	8,832	1,862
Total	1,544	9,353	8,908	1,989
1979:				
97.0%-99.9%	108	5	7	106
99.99%	15	34	45	4
99.999%	5	70	72	3
99.9999%-99.99999%	1,748	9,101	9,337	1,512
Total	1,876	9,210	9,461	1,625

[1] Consumers only.

[2] Ending stocks for 1978 do not equal 1979 beginning stocks because of reported beginning stock adjustments.

STOCKS

Consumer stocks of gallium metal at yearend 1978 and 1979, both commercial and high-purity grades, are shown in table 3.

PRICES

Throughout 1978, the American Metal Market quoted prices for metal of 99.9999% purity at $500 to $600 per kilo in 100-kilogram lots. At the end of 1979, the price was quoted at $510 per kilogram in 100-kilogram lots. Gallium prices are subject to negotiation between buyer and seller.

FOREIGN TRADE

Data on the export of gallium metal and compounds are not reported separately but are included in the export category "base metals and alloys, not elsewhere classified, wrought or unwrought, waste and scrap." Significant quantities of gallium and gallium compounds are exported as parts of manufactured gallium-based electronic and electrical components and equipment.

Imports of gallium in 1978 and 1979 increased substantially in quantity and value from those of 1977 and augmented the U.S. supply available for consumption. In both years, Switzerland was the major source of imported metal. The average value of imported metal declined from $430.51 per kilogram in 1977 to $415.28 in 1978 and increased to $417.37 in 1979.

Table 4.—U.S. imports for consumption of gallium (unwrought, waste and scrap), by country

Country	1978		1979	
	Kilograms	Value	Kilograms	Value
Canada	75	$52,608	450	$203,431
Czechoslovakia	--	--	53	16,201
Germany, Federal Republic of	748	339,806	218	85,716
Hungary	37	13,629	59	17,526
Italy	--	--	--	--
Japan	100	31,500	41	22,452
Netherlands	--	--	41	17,180
Switzerland	2,628	1,062,700	5,498	2,289,820
United Kingdom	138	45,023	41	19,228
Total	3,721	1,545,266	6,401	2,671,554

WORLD REVIEW

Data on world consumption and production of gallium are not available. However, significant quantities of gallium metal and compounds are probably consumed by countries with large, well-developed electronic and electrical industries. Based on 1978 and 1979 U.S. imports of gallium, the rest-of-world gallium production probably increased significantly.

TECHNOLOGY

A solar cell was described that converts sunlight into electricity with a 28.5% conversion efficiency. A mirror focused solar energy on a special filter that splits incoming light waves into low-energy long light waves and high-energy short light waves. The lower energy waves are directed to a silicon cell, and the high-energy waves pass through the filter to an aluminum-gallium arsenide conversion cell. Conversion efficiency was improved because the two-cell system used a wider range of light energy.[2]

A recent paper reviewed the supply-demand situation for gallium and also discussed recovery technology.[3]

Gallium extraction from an alkaline aluminate solution obtained from the recovery of aluminum from nepheline ore was described.[4]

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Table 4.—U.S. imports for consumption of gallium [illegible] by country

WORLD REVIEW

During [illegible] world consumption and production of gallium were not available. However, significant quantities of gallium metal and compounds are probably consumed in countries with large, well-developed electronic [illegible]

TECHNOLOGY

[illegible] the lower energy wave was absorbed [illegible] through the filter to an aluminum gallium arsenide [illegible]

A recent paper reviewed the toxicology [illegible] for gallium and [illegible]

[illegible]

Gem Stones

By G. David Baskin[1]

The value of gem stones and mineral specimens produced in the United States during 1978 was estimated to be $8.9 million. Production in 1979 decreased to an estimated $8.2 million. During both years, turquoise production decreased while tourmaline and sapphire production increased. Amateur collectors accounted for much of the activity in many States. Commercial operators produced rough jade, jasper, agate, sapphire, turquoise, opal, and tourmaline, which they sold mainly to wholesale or retail outlets and also to jewelry manufacturers.

DOMESTIC PRODUCTION

Mines and collectors in 39 States produced gem materials with an estimated value of $1,000 or more in each State in 1978. Nine States supplied 89% of the total value, as follows: Arizona, $4.6 million; Maine, $1 million; Nevada, $1 million; Oregon, $600,000; California, $240,000; Wyoming, $200,000; New Mexico, $180,000; Texas, $170,000; and Washington, $170,000. In 1979, estimated production in Arizona and Oregon decreased to $4 million and $500,000, respectively, while other values remained the same.

Park authorities at the Crater of Diamonds Park in Pike County, Ark., reported 120,000 people visited the park in 1978 and found 608 diamonds. The largest was an 8.5-carat, brown stone of undetermined value. Most of the stones are off-white to brown; however, yellow, pink, and green stones are also found. During 1979, the park had 85,400 visitors, and 411 diamonds were found. The largest stone found weighed 5.1 carats. The decrease in attendance reflected a general decrease in tourism around the country; however, "dig for fee" operations remained popular.

In 1978, new tourmaline pockets were found in the Mt. Mica pegmatites near West Paris, Maine. The green and blue crystals should yield several cut stones up to 100 carats each. Some of the tourmaline from the Dunton Quarry, Oxford County, was used to create miniature sculptures of animal life native to North America. The gem carvings, some made with several colors of Maine tourmaline, were completed in Idar-Oberstein, the Federal Republic of Germany, and exhibited at national gem shows in the United States.[2] In 1979, one of the largest gem tourmaline-bearing cavities ever discovered in the United States was found at Mt. Mica.

In San Diego County, Calif., tourmaline is being produced at the reopened Himalaya Mine. The Tourmaline Queen and Pala Chief mines, in the same county, continue to produce fine gem-quality and specimen tourmaline and morganite.

Small quantities of rare red beryl crystals are being mined in a rhyolite in the Wah Wah Mountains in Beaver County, Utah. Much of the material is sold as mineral specimens; however, some fine cut stones have been available. The finer stones, none weighing over 3 carats, have sold for $3,000 per carat.

In Mitchell County, N.C., a small pocket of emerald was found at the old Crabtree mine. Several of the crystal specimens would yield fair to good cut stones weighing 1 to 1.5 carats.

Sapphire mining continued at Yogo Gulch, Mont. The mine is producing some very fine blue stones. Three carats has been the maximum size cut stone available.

In Rabun County, Ga., and Macon County, N.C., small quantities of gem-quality smoky quartz have been found.

Gem-quality aquamarine has been found in decomposed pegmatite in the mountains near Pierce, Idaho.

CONSUMPTION

Domestic gem stone output went to amateur and commercial rock, mineral, and gem stone collections, objects of art, and jewelry. Apparent consumption (domestic production plus imports minus exports and reexports) in 1978 was $1,447 million, 39% more than that of 1977. During 1979, apparent consumption decreased to $1,238 million.

PRICES

A sampling of prices which colored-stone dealers in various U.S. cities charged their customers during December 1979 follows:[3]

Gem stone	Carat weight	Price range per carat	Median price per carat	
			Early December 1979	December 1978[1]
Amethyst	10	$14- $28	$15	$15
Aquamarine	5	55- 300	168	100
Cat's eye (chrysoberyl)	2	290-1,500	850	800
Citrine	10	8- 18	12	9
Emerald:				
Medium to better	1	1,600-4,675	3,150	2,700
Commercial	1	250-1,500	900	900
Garnet, green (tsavorite, demantoid)	1	425- 850	600	475
Opal, black	3	350- 750	500	400
Opal, white	5	60- 125	75	75
Peridot (variety of olivine)	5	45- 90	65	55
Ruby:				
Medium to better	1	950-4,000	1,830	1,250
Commercial	1	450-1,550	590	500
Sapphire:				
Medium to better	1	450-2,500	750	600
Commercial	1	90- 630	225	150
Star sapphire:				
Sky-blue	5	80- 900	250	250
Grey	5	25- 150	100	83
Tanzanite (blue-violet zoisite)	5	300- 700	500	413
Topaz	5	150- 265	245	193
Tourmaline, green	5	30- 110	70	46
Tourmaline, pink	5	30- 145	80	70

[1] Adjusted from Keystone prices formerly published.

A sampling of prices which diamond dealers in various U.S. cities charged their customers in December 1979 follows:[4]

Carat weight	Description, color[1]	Clarity[2] (GIA terms)	Price range per carat	Median price per carat	
				Early December 1979	December 1978[3]
0.04-0.08	G-I	VS$_1$	$450- $755	$587	$611
.04- .08	G-I	SI$_1$	385- 615	540	546
.09- .16	G-I	VS$_1$	475- 872	640	731
.09- .16	G-I	SI$_1$	425- 695	595	643
.17- .22	G-I	VS$_1$	740- 1,495	960	945
.17- .22	G-I	SI$_1$	675- 1,315	895	850
.23- .28	G-I	VS$_1$	840- 1,745	1,220	1,115
.23- .28	G-I	SI$_1$	700- 1,535	1,000	982
.29- .35	G-I	VS$_1$	935- 1,960	1,400	1,242
.29- .35	G-I	SI$_1$	775- 1,690	1,120	1,065
.46- .55	G-I	VS$_1$	1,600- 2,488	1,950	1,565
.46- .55	G-I	SI$_1$	1,250- 2,140	1,540	1,348
.69- .79	G-I	VS$_1$	2,000- 3,185	2,605	2,035
.69- .79	G-I	SI$_1$	1,500- 2,746	2,103	1,861
1.00-1.15	D	FL	35,000-38,500	37,000	22,500
1.00-1.15	E	VVS$_1$	14,000-19,500	17,000	NA
1.00-1.15	G	VS$_2$	4,428- 7,500	6,100	NA
1.00-1.15	H	VS$_2$	3,500- 5,700	4,650	NA
1.00-1.15	I	SI$_1$	2,500- 4,300	3,170	NA

NA Not available.

[1] Gemological Institute of America color grades: D—colorless; E—rare white; G-I—traces of color.

[2] Clarity: *FL*—no blemishes; VVS$_1$—very, very slightly included; VS$_1$—very slightly included; VS$_2$—very slightly included, but more visible; SI$_1$—slightly included.

[3] Adjusted from Keystone price formerly published.

The retail price of a finest quality, 1-carat diamond tripled between December 1976 and December 1978. This was due in part to devaluation of the U.S. dollar and the fact that the diamond market became very speculative early in 1978. In order to dampen speculation in the resale of rough gem-quality stones, De Beers Consolidated Mining, the South African company controlling 85% of the world's diamonds, imposed a 40% surcharge on its April sales of rough stones; during May, June, and July, the surcharge was reduced to 25%, 15%, and 10%, respectively. The surcharge had the desired effect in that it quelled speculation and suspected hoarding of rough diamond at a time when De Beers' supplies were believed to be limited. Following the removal of the surcharge, De Beers raised prices an average of 30%. In September 1979, De Beers' prices again rose an overall 13%; the largest increase affected cut stones weighing over one-half carat.

Emerald prices decreased in 1979 approximately 10% in all but the finest qualities. An increase in the supply of Zambian stones brought the decline.

Other precious and semiprecious stones also increased in price and popularity. Many buyers turned to colored stones as fine diamonds became more expensive.

FOREIGN TRADE

The following section contains foreign trade statistics for 1978 and for 1979 (in parentheses).

Exports by the United States of all gem materials amounted to $492.7 ($661.0) million, and reexports to $290.7 ($279.0) million. Diamond accounted for 93% (94%) of the value of exports and 96% (94%) of the reexports. Exports of diamond totaled 332,199 (213,481) carats valued at $457.1 million ($623.1 million). Of this total, diamond cut but unset, suitable for gem stones not over 0.5 carat, was 49,057 (59,300) carats valued at $41.7 million ($69.5 million); and cut but unset, over 0.5 carat was 170,316 (145,864) carats valued at $402.1 million ($552.5 million). Exports of uncut diamond were 112,826 (8,317) carats valued at $13.3 million ($1.1 million).

Reexports of diamond amounted to 1,266,998 (982,027) carats valued at $279.6 million ($261.5 million), in categories as follows: Rough or uncut, suitable for gem stones, not classified by weight, 1,179,038 (913,981) carats valued at $169.1 million ($150.1 million); cut but unset, not over 0.5 carat, 37,742 (42,841) carats valued at $18.8 million ($25.1 million); cut but unset, over 0.5 carat, 50,218 (25,205) carats, valued at $91.7 million ($86.3 million).

Exports of all other gem materials by the United States amounted to $27.5 million

($37.7 million). Of this total, pearls, natural and cultured, not set or strung, were valued at $3.9 million ($0.8 million). Natural precious and semiprecious stones, unset, were valued at $21.7 million ($33.9 million); and synthetic or reconstructed stones, unset, were valued at $1.9 million ($3.0 million). Reexports of all other gem materials amounted to $12.3 million ($18.4 million) in categories as follows: Pearls, $1.2 million (less than $0.1 million); natural precious and semiprecious stones, unset, $10.9 million ($18.2 million); synthetic or reconstructed stones, unset, $0.2 million ($0.2 million).

In 1978, imports by the United States of gem materials increased 36% in value over those of 1977; diamond accounted for 88% of the total value of gem material imports. In 1979, imports of gem materials decreased 2% in value from those of the previous year; diamond accounted for 86% of the total value of gem material imports.

Although rough and uncut diamond imports were reported from 31 (27) countries, 99% (99%) of the value was from 9 countries. Cut but unset diamond, not over 0.5 carat, was imported from 41 (40) countries; however, the imports of this category from 10 countries amounted to 99% (98%) of total carats and value. Cut but unset diamond, over 0.5 carat, was imported from 28 (33) countries; the imports from 8 countries amounted to 99% (99%) of the total carats and 98% (99%) of the value.

Emerald imports increased 5% (39%) in quantity and 28% (28%) in value. Emerald was imported from 42 (40) countries; the imports from 12 countries amounted to 97% (97%) of the carats and 93% (95%) of the value. Rubies were imported from 34 (31) countries; the imports from 9 countries amounted to 98% (98%) of the value. Sapphires were imported from 34 (35) countries; the imports from 10 countries amounted to 98% (97%) of the value.

Natural pearls and parts from 12 (18) countries increased 54% (192%) in value of imports; 5 countries accounted for 93% (79%) of the value as follows: India, $291,000 ($820,326); Burma, $215,000 ($238,694); Japan, $136,000 ($566,669); China, mainland, $89,000 ($196,720); and Hong Kong, $50,000 ($110,357). Imports of cultured pearls increased 49% (46%) in value, and were received from 18 (23) countries; Japan, at $24.6 ($36.2) million, accounted for 90% (91%) of the value. Imports of imitation pearls decreased 2% (increased 43%) in value; Japan, at $582,000, ($1,223,763) accounted for 63% (93%) of the value. Coral, cut but unset, and cameos suitable for use in jewelry decreased 3% (18%) in value of imports, which were received from 17 (16) countries; 3 countries accounted for 95% (91%) of the value as follows: Taiwan, $2.2 million (1.5 million); Italy, $1.4 million ($1.4 million); and Japan, $0.5 million ($0.3 million).

Imports of other precious and semiprecious stones, rough and uncut, increased 52% (21%) in value and came from 51 (48) countries, of which 9 countries accounted for 82% (83%) of the value. Other precious and semiprecious stones, cut but unset, increased 34% (decreased 7%) in value and were imported from 55 (54) countries, of which 5 countries accounted for 86% (83%) of the value. Synthetic gem stones, cut but unset, increased 48% (46%) in value and came from 20 (28) countries, of which 7 accounted for 93% (88%) of the value. Imitation gem stones increased 25% (2%) in value and came from 20 (22) countries, of which 5 countries accounted for 93% (94%) of the value.

Table 1.—U.S. exports and reexports of diamond (exclusive of industrial diamond), by country

Country	1978		1979	
	Quantity (carats)	Value (millions)	Quantity (carats)	Value (millions)
Exports:				
Belgium-Luxembourg	46,153	$60.4	33,589	$110.5
Canada	3,375	2.7	5,503	4.9
France	6,087	17.2	4,606	26.2
Hong Kong	107,790	208.6	73,854	243.1
India	8,427	.6	340	.2
Israel	59,501	17.8	23,966	21.4
Japan	33,493	56.9	35,792	72.0
Netherlands	11,758	14.9	565	1.5
Switzerland	28,730	49.1	18,249	104.2
United Kingdom	11,113	12.5	4,349	14.1
Other	15,772	21.4	12,668	25.0
Total	332,199	457.1	213,481	623.1
Reexports:				
Belgium-Luxembourg	485,011	83.7	354,873	86.4
France	13,649	8.1	9,688	8.3
Hong Kong	36,812	27.4	12,812	22.1
India	119,643	2.7	126,763	3.2
Israel	373,393	74.5	295,662	63.9
Japan	12,270	12.1	10,528	11.3
Netherlands	96,693	27.1	53,468	8.9
Switzerland	14,242	16.1	13,076	27.6
United Kingdom	94,773	22.6	94,573	24.7
Other	20,512	5.3	10,584	5.1
Total	1,266,998	279.6	982,027	261.5

Table 2.—U.S. imports for consumption of diamond (cut but unset), by kind and country

Kind and country	1978		1979	
	Quantity (carats)	Value (millions)	Quantity (carats)	Value (millions)
Cut but unset, not over 0.5 carat:				
Belgium-Luxembourg	865,804	$271.1	557,859	$187.0
France	6,170	2.1	3,583	1.4
Hong Kong	6,153	2.1	10,172	2.1
India	1,060,948	241.6	769,769	172.9
Israel	876,100	305.0	676,353	241.9
Sierra Leone	5,223	1.7	4,565	2.2
South Africa, Republic of	26,217	15.1	20,655	13.8
Switzerland	7,428	5.7	13,277	7.0
United Kingdom	25,804	8.6	14,141	6.0
U.S.S.R	20,120	9.2	12,651	6.0
Other	25,201	7.7	27,778	10.8
Total	2,915,168	869.9	2,110,803	651.1
Cut but unset, over 0.5 carat:				
Belgium-Luxembourg	145,857	131.1	127,277	138.1
India	6,803	3.3	5,390	2.1
Israel	91,985	63.5	77,190	66.3
Netherlands	3,315	4.1	2,794	2.6
South Africa, Republic of	12,723	17.1	9,545	19.8
Switzerland	4,948	8.5	5,181	10.7
United Kingdom	7,382	8.7	4,551	7.8
U.S.S.R	4,511	3.5	1,530	1.9
Other	2,108	3.2	2,072	2.3
Total	279,632	243.0	235,580	251.6

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Table 3.—U.S. imports of precious and semiprecious gem stones, by kind and country

Kind and country	1978 Quantity (carats)	1978 Value (millions)	1979 Quantity (carats)	1979 Value (millions)
Emerald:				
Belgium-Luxembourg	35,186	$0.2	4,175	$0.4
Brazil	107,901	4.1	94,237	4.8
Colombia	66,095	31.4	205,129	45.1
Germany, Federal Republic of	29,790	2.2	21,511	2.5
Hong Kong	139,235	5.7	126,097	8.0
India	908,706	13.9	1,073,987	14.4
Israel	106,285	8.2	71,718	13.8
Japan	13,478	.1	876	.2
South Africa, Republic of	52,381	.1	2,551	1.0
Switzerland	81,681	9.0	13,352	6.8
Tanzania	18,858	.03	--	--
United Kingdom	34,749	1.6	5,186	2.6
Other	48,304	5.5	58,410	5.4
Total	1,642,644	82.2	2,277,231	105.1
Ruby:				
Burma	NA	.1	NA	.3
Germany, Federal Republic of	NA	.5	NA	.4
Hong Kong	NA	1.2	NA	2.1
India	NA	1.2	NA	1.7
Israel	NA	.4	NA	.4
Sri Lanka	NA	.5	NA	.3
Switzerland	NA	.9	NA	1.0
Thailand	NA	17.8	NA	23.0
United Kingdom	NA	.3	NA	.2
Other	NA	.4	NA	.5
Total	NA	23.4	NA	30.0
Sapphire:				
Australia	NA	.2	NA	.1
Burma	NA	.1	NA	.04
Germany, Federal Republic of	NA	.4	NA	.4
Hong Kong	NA	1.6	NA	1.4
India	NA	.8	NA	.9
Israel	NA	.1	NA	.2
Sri Lanka	NA	3.9	NA	3.4
Switzerland	NA	1.2	NA	1.2
Thailand	NA	14.3	NA	15.0
United Kingdom	NA	.4	NA	.2
Other	NA	.4	NA	.7
Total	NA	23.4	NA	23.5
Other:				
Rough, uncut:				
Australia	NA	1.2	NA	1.8
Brazil	NA	3.7	NA	2.1
Colombia	NA	2.1	NA	1.8
Israel	NA	.9	NA	.6
Kenya	NA	.4	NA	.3
Netherlands	NA	.4	NA	--
South Africa, Republic of	NA	.6	NA	3.3
Switzerland	NA	1.7	NA	3.0
Zambia	NA	2.1	NA	1.5
Other	NA	2.7	NA	2.2
Total	NA	15.8	NA	19.2
Cut but unset:				
Australia	NA	2.5	NA	2.4
Brazil	NA	12.2	NA	11.2
Germany, Federal Republic of	NA	5.2	NA	5.3
Hong Kong	NA	19.9	NA	17.2
Taiwan	NA	1.5	NA	.5
Other	NA	6.5	NA	7.7
Total	NA	47.8	NA	44.3

NA Not available.

Table 4.—Value of U.S. imports of synthetic and imitation gem stones, by country

(Million dollars)

Country	1978	1979
Synthetic, cut but unset:		
Austria	1.9	5.1
France	.9	4.0
Germany, Federal Republic of	6.9	2.8
Japan	1.3	.3
Korea, Republic of	.7	.9
Switzerland	1.7	3.8
Taiwan	.9	.5
Other	1.2	5.2
Total	15.5	22.6
Imitation:		
Austria	6.3	8.2
Czechoslovakia	1.1	1.3
Germany, Federal Republic of	4.3	3.1
Japan	.4	.3
Switzerland	.3	.1
Other	1.1	.8
Total	13.5	13.8

Table 5.—U.S. imports for consumption of precious and semiprecious gem stones

(Thousand carats and thousand dollars)

Stones	1977		1978		1979	
	Quantity	Value	Quantity	Value	Quantity	Value
Diamonds:						
Rough or uncut	2,909	638,205	2,488	648,651	2,120	956,240
Cut but unset	3,502	806,232	3,193	1,112,907	2,247	902,755
Emeralds: Cut but unset	1,563	64,375	1,643	82,237	2,277	105,064
Coral, cut but unset, and cameos suitable for use in jewelry	NA	4,410	NA	4,287	NA	3,511
Rubies and sapphires: Cut but unset	NA	33,544	NA	46,858	NA	58,518
Marcasites	NA	58	NA	40	NA	134
Pearls:						
Natural	NA	544	NA	840	NA	2,458
Cultured	NA	18,260	NA	27,152	NA	39,055
Imitation	NA	942	NA	926	NA	1,321
Other precious and semiprecious stones:						
Rough and uncut	NA	10,448	NA	15,888	NA	19,196
Cut but unset	NA	35,617	NA	47,809	NA	44,319
Other n.s.p.f	NA	3,273	NA	3,951	NA	4,768
Synthetic:						
Cut but unset number (thousands)	15,758	10,391	17,883	15,886	20,223	22,579
Other	NA	864	NA	1,074	NA	1,485
Imitation gem stones	NA	10,841	NA	13,506	NA	13,814
Total	XX	1,638,104	XX	[1]2,221,511	XX	2,170,904

NA Not available. XX Not applicable.

[1] Data do not add to total shown because of independent rounding.

Table 6.—U.S. imports for consumption of diamond (exclusive of industrial diamond), by country

(Thousand carats and thousand dollars)

Country	1977				1978				1979			
	Rough or uncut		Cut but unset		Rough or uncut		Cut but unset		Rough or uncut		Cut but unset	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Belgium-Luxembourg	22	7,592	1,257	307,766	26	9,968	1,012	402,190	40	12,042	685	325,065
Bolivia	--	--	--	--	--	--	--	--	1	180	--	--
Brazil	(1)	91	4	880	9	1,274	4	1,258	18	2,201	7	2,875
Canada	(1)	49	1	704	--	--	2	1,249	9	171	2	1,087
Central African Empire	51	3,539	--	--	66	6,458	--	--	75	5,267	--	--
France	8	683	9	1,577	(1)	8	6	2,183	(1)	339	4	1,491
Germany, Federal Republic of	(1)	8	4	906	--	--	1	368	--	--	2	1,318
Ghana	8	64	--	--	(1)	4	--	--	--	--	--	--
Hong Kong	1	98	9	1,741	(1)	1	7	3,164	--	--	11	3,066
India	(1)	1	769	130,501	(1)	100	1,058	244,885	1	83	776	175,016
Ireland	1	413	2	305	--	--	--	--	--	--	--	--
Israel	57	11,177	1,260	304,283	50	17,719	968	388,424	59	18,406	754	308,177
Italy	--	--	2	641	--	--	1	651	--	--	(1)	113
Japan	(1)	27	1	286	2	15	3	1,124	--	--	1	558
Liberia	1	228	--	--	70	14,286	(1)	2	32	7,726	--	--
Mauritania	5	45	(1)	23	--	--	--	--	(1)	65	--	--
Netherlands	29	12,465	54	12,489	44	15,585	8	5,770	15	11,158	7	4,163
Sierra Leone	186	40,467	4	881	146	52,386	5	1,688	123	51,628	5	2,165
South Africa, Republic of	1,096	315,790	33	16,905	1,221	550,442	30	32,725	1,134	671,526	30	33,591
Switzerland	6	811	8	3,003	5	743	12	14,198	6	6,871	18	17,606
Tunisia	--	--	3	548	--	--	(1)	115	--	--	--	--
U.S.S.R	--	--	44	14,089	(1)	1	25	12,668	(1)	22	14	7,928
United Kingdom	1,281	238,608	32	7,073	497	155,544	33	17,286	296	145,389	19	13,797
Venezuela	155	5,381	--	--	313	20,819	(1)	4	308	20,324	(1)	61
Other Africa, n.e.c	(1)	23	--	--	2	775	2	261	27	1,367	(1)	234
Other	2	645	6	1,771	12	2,528	7	2,719	4	1,606	12	4,394
Total	2,909	638,205	3,502	806,332	2,463	848,651	3,193	1,112,907	[2]2,120	956,340	2,347	902,755

[1] Less than 1/2 unit.

[2] Data do not add to total shown because of independent rounding.

WORLD REVIEW

Angola.—The Angola Diamond Co. mines diamond on concessions comprising 50,000 square kilometers in the northeastern region of the country. After a considerable drop in production because of internal strife in 1976 and 1977, partial recovery was achieved in 1978, with the mining of more than 700,000 carats of gem-quality diamond.[5] A 137-carat diamond was found in the Lucapa mine area in North Lunda Province.[6]

Australia.—Diamond exploration in the Kimberley region of Western Australia stirred much excitement during 1978 and 1979. More than 5,700 claims of 120 hectares each were staked by 23 exploration groups representing 45 to 55 different companies. The most promising results were shown by the Ashton Joint Venture, which is managed by a subsidiary of Conzinc Riotinto of Australia Ltd. Initial sampling of several of the 28 kimberlite pipes located in 1978 yielded more than 4,200 stones of industrial and gem-quality. The largest stone found weighed 5.7 carats, but the average weight was less than 0.1 carat. In October 1979, a group managed by Conzinc Riotinto found a pipelike structure of diamond-bearing kimberlite in the Lake Argyle area in Western Australia near the Northern Territory border. The pipe, covering 111 acres at the surface yields about 150 carats for each 100 metric tons of kimberlite ore. Alluvial deposits in the same area have much higher yield. The prospect has yielded more than 5,000 carats; the largest stone weighed 7.03 carats. The quality of the stones has not been ascertained. The claims will not be firmly evaluated until 1980 when more extensive bulk sampling and sample processing will be complete.[7 8]

A large ruby field was discovered at Ambalindum Station northeast of Alice Springs in central Australia. The property owner has said that it is among the three most important ruby discoveries in the world.[9]

A sapphire deposit near Mt. Garnett in north Queensland is yielding stones up to 10 carats. The area has been set aside by the Government for hand miners.[10]

Annual value of opal production at Lightning Ridge in northern New South Wales has reached $A7 million. Prices up to $5,000 per carat for black opals are reported to have been offered. Prices are said to be increasing 20% annually. It is hoped that with increased open cut mining at Lightning Ridge, this area will eventually rival the South Australia production from the opal fields at Coober Pedy.[11]

Botswana.—The Jwaneng mine now being developed will reportedly add 6 million carats to the annual diamond production of Botswana by 1985, making that country one of the world's major producers ranking behind Zaire and the Soviet Union. Located in the Kalahari Desert, the mine is a joint project between the Botswana Government and De Beers Consolidated Mines Ltd. The Government will receive 77.5% of the profits.[12]

The diamond mines at Orapa and Letlhakane were recently expanded. The Orapa mine increased its output from 2.5 million to 4.1 million carats, and an expansion to the facilities at Letlhakane raised production from 330,000 to 400,000 carats per year at the end of 1979. The mines are operated by Debswana, a joint company owned equally by De Beers and the Botswana Government.[13]

Central African Empire.—Diamond production in 1978 was 284,240 carats, 70% being gem-quality. Total production decreased 5.6% from the 1977 level, while increased prices resulted in the value of production rising 49% to $35 million.[14] An Israeli-Iranian-Swiss group obtained a 30,000-square-kilometer concession for diamond exploration and evaluation; however, the group's project was dissolved when political instability in Iran increased.[15]

Colombia.—In the first 7 months of 1979, Colombia exported emeralds worth $75 million. Total production in 1978 was $40 million compared with $2 million in 1973, when some state-owned mines at Muzo, Coscuez, and Penas Blancas, beset by theft and violence, were occupied by the army. These have since been taken over by private consortia and returned to full production.[16]

India.—Buying and selling diamonds became much easier with the formation of two new facilities. The Hindustan Diamond Co., Ltd., has been set up jointly by the Indian Government (50%), the Bank of Bermuda's UK branch (30%), and the Industrial Investment Trust, Ltd. (20%). The company will be involved in obtaining and distributing rough diamonds on a regular basis to the country's diamond industry. The service will be particularly beneficial to the 10,000 small processing units and artisans. A diamond exchange is being set up in Bombay with the claim that this will eliminate loss of revenue caused by having to go through Antwerp or Hong Kong for sales to the international market.[17] A task force organized by the Government has set an export target of Rs210 billion by 1982-83, a 300% increase over present levels.[18]

Due to substantial cuts in imports by the United States and Europe, export values for December 1978 were only one-half those of November. During the first half of 1979, diamond exports recovered enough to allow reinstatement of some of the 150,000 workers laid off during the recession.[19] [20]

Israel.—In 1978, exports of polished diamonds totaled 2,570,000 carats with a net value of $1,317 million, a 31% increase over the 1977 export values.[21] Exports from January through November of 1979 had a value of $1,129 million, a 7% decrease compared to the same period in the previous year.

Kenya.—A 3-year survey carried out under a bilateral agreement between Austria and Kenya has resulted in estimates that the gem stone belt of Kenya, running from the Taiti Hills to the Tanzanian border, contains rubies worth between K Sh 40 million and 80 million.[22] Minable deposits yield fine rubies up to 1 carat and rivaling the Burmese rubies in color. An aquamarine occurrence is producing light-blue clean stones selling for $30 to $100 per carat. Traders in Kenya have accumulated substantial quantities of Tanzanian tsavorite (green garnet) for which they are asking unusually high prices.

Lesotho.—Two exceptionally large fine diamonds were recovered at the Letseng-laterai mine high in the Maluti Mountains. In February 1978, a 98-carat stone was found followed by a 130.4-carat stone in July. According to De Beers, the mine's profits depend on the occasional large stone, since most of the ore is low grade.[23]

Pakistan.—Three years' exploration has turned up several major gem deposits in northern Pakistan. An area of 30 square miles in the Hunza Valley contains rich lodes of ruby, emerald, sapphire, quartz, garnet, tiger's eye, moonstone and pyrite.[24]

The Government of Pakistan formed the Gemstone Corp. for the mining, cutting, polishing, marketing, and export of the country's gems. As a subsidiary of the Pakistan Mineral Development Corp., the new corporation will manage the Swat emerald mine, the Hunza ruby mines, and the lapidary center in Peshawar. From July 1977 to June 1978, 42.2 million carats of rubies was recovered at the Hunza deposits.[25] [26]

Rhodesia, Southern.—Pilot plant testing of a diamond deposit near Beitbridge is underway. The prospect belongs to De Beers Consolidated Mines, Ltd.[27]

South Africa, Republic of.—Diamond production in 1978 is estimated at 7.7 million carats with 3.6 million carats being of gem-quality. This represents a 1% increase from total production in 1977. The 1979 total production is estimated to have decreased slightly to 7.64 million carats.

De Beers continued plans to increase diamond production from all its mining interests to over 20 million carats by the mid-1980's.[28] In South Africa, De Beers' plans include increasing ore production and plant capacity and improving diamond recovery techniques. Marked improvement in recovery methods in the last 10 years has led to the retreatment of old mine dumps in and around Kimberley, a move intended to extend the life of the older underground mines, some of which were expected to be exhausted before 1990.[29]

The Premier mine, one of De Beers' most important producers, yielded a white diamond totaling 353.9 carats uncut. It has been cut and shaped as a tear-drop pendant. The company also announced reaching an agreement with the South African Government for the further development of the mine, which has produced over 78 million carats including 280 stones weighing over 100 carats each. The mine will be extended below a 75-meter-thick barren gabbro sill which cuts across the kimberlite pipe at the 400-meter level. The kimberlite below the sill is expected to yield 14 million tons of ore at a grade of 72 carats per hundred tons.[30] [31]

In northwestern Cape Province the Koingnaas mine began production planned at 540,000 carats per year with an apparent operating life of 15 years. The alluvial deposit will yield small stones averaging 0.25 carat or less. Discovered in 1962, the deposit could not be economically mined until the recent sharp increases in diamond prices and improvement in market conditions for small stones.[32]

The Finsch mine, in the same province, will increase its ore production by about 40% to 420,000 tons per month. In addition, the treatment plant plans to increase capacity and substantially improve diamond recovery. On the basis of a 6-day working week, the new capacity is aimed at increasing the mine's diamond production of 2.4 million carats per year by about 1 million carats per year.[33] Gem stone recoveries presently run at about 15% of the total diamond production.

Domestic diamond cutting labor was expected to increase to 4,500 by the end of 1979, a 400% expansion over the number employed in early 1978. The industry could soon handle 5 million carats per year.[34]

An expansion program has begun that will increase the De Beers/Sibeka synthetic industrial diamond production capacity to more than 60 million carats annually. This would amount to 60% of the 1978 synthetic diamond world market. The three-phase program, which includes plants in the Republic of South Africa, Ireland, and Sweden, is expected to be complete in 1980.[35]

Sri Lanka.—As part of the jewelry export drive to be implemented by the export development board, Sri Lanka is once again to import diamonds. This move follows a ban on diamond imports (which has lasted over two decades) and is one of several moves initiated by the board in an attempt to achieve jewelry exports in 1980 worth $1 million.[36]

Tanzania.—Salmon-pink to cinnamon-orange "malaya" garnet is being mined in the Umba Valley. Stones larger than 10 carats are rare and may bring several hundred dollars per carat.

U.S.S.R.—Diamond exports, estimated at $750 million in 1978 are the Soviet Union's fourth largest hard currency earner.[37] An estimated 10.6 million carats were mined in 1978, 20% being of gem-quality.

The Soviets introduced a new ornamental gem stone in the United States. Charoite is a lilac-purple stone composed of calcium potassium silicate with areas of greenish black massive or acicular aegirine-augite and orange tinkasite. With a hardness of 5 to 6 (Moh's scale) it is well suited for carving and cabbing.[38]

A large turquoise deposit was found in Armenia. Fine green turquoise and chrysoprase finds are reported in Kazakhstan. Several new nephrite deposits have been found; colors range from white and chocolate brown to emerald green. New blue topaz and aquamarine finds have also been reported.

The Soviet Union, while increasing its production of natural precious and semiprecious stones, is also synthesizing and marketing fine-quality emerald and amethyst.

Zaire.—Diamond production (11.2 million carats in 1978) was reported to be unaffected by unrest in Shaba Province. The diamond-producing areas of Kasai are 200 miles north of the troubled area. Zaire markets its diamonds (95% to 97% industrial quality) through De Beers' Central Selling Organization.

Zambia.—Emerald deposits in the Ndola District may be exploited by Mukashala Ltd., a company formed by five Zambian chiefs. If a mining license is granted, the company will employ villagers presently mining illegally.[39]

Table 7.—Diamond (natural): World production, by type and country[1]

(Thousand carats)

Country	1976			1977			1978[p]			1979[e]		
	Gem	Industrial	Total	Gem	Industrial	Total	Gem	Industrial	Total	Gem	Industrial	Total
Africa:												
Angola	255	85	340	265	88	353	525	175	700	562	188	750
Botswana	358	2,026	2,384	404	2,287	2,691	418	2,367	2,785	500	2,840	3,340
Central African Empire	172	114	286	178	119	297	199	85	284	210	90	300
Ghana	228	2,055	2,283	[r]230	[r]1,717	1,947	142	1,281	1,423	150	1,350	1,500
Guinea[e]	25	55	80	25	55	80	25	55	80	27	58	85
Ivory Coast	[r]22	[r]38	60	[r]7	[r]11	[r]18	--	10	10	--	5	5
Lesotho	1	4	5	7	35	42	13	53	66	14	56	70
Liberia[2]	[r]163	[r]162	[r]325	163	163	326	128	180	308	130	180	310
Sierra Leone	[r]433	[r]650	[r]1,083	423	538	961	283	424	707	285	425	710
South Africa, Republic of:												
Premier mine	458	1,375	1,833	502	1,508	2,010	496	1,487	1,983	495	1,485	1,980
Other De Beers properties[3]	2,549	2,086	4,635	2,796	2,287	5,083	2,903	2,376	5,279	2,900	2,300	5,200
Other	333	222	555	[r]330	[r]220	[r]550	279	186	465	275	185	460
Total	3,340	3,683	7,023	[r]3,628	[r]4,015	[r]7,643	3,678	4,049	7,727	3,670	3,970	7,640
South-West Africa, Territory of, (Namibia)	1,609	85	1,694	1,901	100	2,001	1,803	95	1,898	1,850	100	1,950
Tanzania	219	219	[2]438	[r]204	[r]204	[r] [2]408	146	147	[2]293	145	145	290
Zaire	591	11,230	11,821	561	10,652	11,213	562	10,688	11,250	560	10,600	11,160
Other areas:												
Brazil	38	38	76	[r]33	[r]32	[r]65	43	43	86	45	45	90
Guyana	6	8	14	7	10	17	7	10	17	7	10	17
India	17	3	20	[r]15	3	[r]18	14	2	16	14	2	16
Indonesia[e]	3	12	15	3	12	15	3	12	15	3	12	15
U.S.S.R.[e]	2,000	7,900	9,900	2,100	8,200	10,300	2,150	8,400	10,550	2,200	8,500	10,700
Venezuela	[r]195	[r]654	[r]849	[r]204	[r]483	[r]687	278	460	738	285	465	750
World total	[r]9,675	[r]29,021	[r]38,696	10,358	28,724	39,082	10,417	28,536	38,953	10,657	29,041	39,698

[e] Estimate. [p] Preliminary. [r] Revised.

[1] Total diamond output (gem plus industrial) for each country is actually reported except where indicated by a footnote to be estimated. In contrast, the detailed separate production data for gem diamond and industrial diamond are Bureau of Mines estimates in the case of every country except Central African Empire (1976-78), Liberia (1976-78), Sierra Leone (1977 and 1978), and Venezuela (1978), for which source publications give details on grade as well as totals. The estimated distribution of total output between gem and industrial diamond is conjectural in the case of a number of countries, based on unofficial information of varying degrees of reliability.

[2] Total exports.

[3] All company output from the Republic of South Africa, except for that credited to the Premier mine; excludes De Beers Group output from Botswana, Lesotho, and the Territory of South-West Africa (Namibia).

TECHNOLOGY

Some diamonds that were once graded as high-quality industrial are now used as low-quality gem stones. This trend is due to increased demand and rising prices as well as increased use of diamond improvement techniques. Stones of poor brown or yellow color can, in some cases, be irradiated and/or heat treated to improve the color to rich coffee, canary yellow, and other colors; small inclusions can be removed with laser treatment, which burns a minute path to the material and oxidizes it.

Heat and irradiation (ultraviolet, X-ray, gamma ray, electron bombardment) are widely used on many precious and semiprecious stones to improve their color.

Heat treatment in aquamarine, topaz, zircon, and tanzanite is very common. With some stones, treatment is permanent and undetectable; others may fade with time and exposure to daylight.[40]

Cubic zirconia, the newest and best of the diamond simulants, increased in popularity and availability. The material consists of zirconium oxide with a compound such as yttrium oxide or calcium oxide added to stabilize the cubic structure. With a very high melting point of 2,750° C, a special technique, skull melting, must be used to obtain large uncontaminated crystals. World production was estimated at 15 million carats of rough in 1978. U.S. consumers purchased an estimated 1 million carats ($40 to $60 million estimated sales) in 1978.[41]

A properly cut cubic zirconia may be indistinguishable from a diamond in an unaided visual examination. However, simple tests of physical properties such as specific gravity, surface wettability, thermal conductivity, and hardness will reveal the difference.

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Gold

By W. C. Butterman[1]

The world price of gold more than tripled in 1978-79. After increasing steadily in 1978 and part of 1979, the price began to rise more steeply and at yearend 1979, impelled by political and economic unrest, was climbing very rapidly towards a peak in January 1980.

Total world mine production remained essentially unchanged, but production in the United States and a few other countries actually decreased somewhat, as mines were enabled to use leaner ores as the price of gold climbed. However, the increasingly strong gold price provided the incentive for extensive exploration for gold deposits and the development of new mines. Retreatment of old tailings dumps, and the heap leaching of low-grade ores, became economically feasible.

The International Monetary Fund (IMF) continued its monthly bullion auctions, begun in 1976, and the U.S. Department of the Treasury auctioned bullion monthly between May 1978 and November 1979. The Treasury bullion, and much of the IMF bullion, was delivered in the United States, but then most of it was promptly exported. Fed by auctioned bullion, U.S. exports tripled in 1979.

Table 1.—Salient gold statistics

	1975	1976	1977	1978	1979
United States:					
Mine production ___ thousand troy ounces___	1,052	1,048	1,100	999	920
Value_______________thousands___	$169,928	$131,340	$163,192	$198,324	$282,833
Ore (dry and siliceous) produced:					
Gold ore _____ thousand short tons___	5,722	3,063	5,806	4,292	6,091
Gold-silver ore _____________do.____	137	1,027	481	738	756
Silver ore_______________do.____	672	651	800	992	962
Percentage derived from:					
Dry and siliceous ores _____________	62	61	60	58	56
Base-metal ores_________________	36	36	38	40	43
Placers ___________________	2	3	2	2	1
Refinery production:					
Domestic ores __ thousand troy ounces___	1,093	954	956	962	795
Secondary (old scrap) ________do.____	1,122	1,068	1,040	1,384	1,681
Exports:					
Commercial ______________do.____	2,689	2,879	7,011	5,509	16,499
Monetary ______________do.____	807	652	1,660	NA	NA
Imports _________________do.____	2,662	2,656	4,454	4,690	4,630
Gold contained in imported coins ___do.____	1,673	1,333	1,614	3,736	2,790
Net sales from foreign stocks in Federal Reserve Bank _____________do.____	577	2,125	6,406	1,569	40
Stocks, Dec. 31:					
Monetary ______________do.____	274.7	274.7	277.6	276.4	264.6
Industrial[1]______________do.____	788	928	1,976	1,672	947
Consumption in industry and the arts ___________________do.____	3,993	4,648	[r]4,868	4,738	4,708
Price:[2] Average per troy ounce _________	$161.49	$125.32	$148.31	$193.55	$307.50
World:					
Production _____ thousand troy ounces___	38,476	[r]39,234	[r]39,121	39,304	39,288
Official reserves[3]______________do.____	1,174.1	1,163.9	1,154.8	1,146.6	1,126.5

[r]Revised. NA Not available.

[1]Unfabricated refined gold held by refiners, fabricators, and dealers.

[2]Engelhard Industries quotations.

[3]Held by market-economy-country central banks and Governments. Source: International Monetary Fund.

Table 2.—Volume of U.S. gold futures trading

(Million troy ounces)

Exchange	Location	1975	1976	1977	1978	1979
Commodity Exchange, Inc	New York	36.19	47.94	98.17	373.40	654.15
New York Mercantile Exchange	do	1.27	.08	.03	.85	.21
International Monetary Market	Chicago	40.70	34.09	90.82	281.30	355.87
Chicago Board of Trade	do	5.56	1.06	1.33	5.49	10.30
Mid-America Commodity Exchange	do	.23	.08	.09	1.50	6.65
Total		83.95	83.25	190.44	662.54	1,027.18

The volume of trading in gold futures on U.S. commodity exchanges quintupled in the 2-year period, exceeding 1 billion ounces[2] in 1979 (tables 1-2).

Legislation and Government Programs.—The U.S. Department of the Treasury held monthly public sales of bullion from May 1978 to November 1979. The IMF also continued its 4-year program, begun in 1976, of public bullion auctions and its restitutions (sales) of bullion to member countries.

On November 10, 1978, the President signed a bill authorizing the minting of 1/2- and 1-ounce gold medallions bearing the images of celebrated American artists. The legislation, effective October 1, 1979, required that 1 million ounces of gold be minted and offered for sale in each of the 5 years 1980-84.

The Federal Trade Commission determined that the amendments to its Trade Practice Rules for the jewelry industry that it proposed in 1977 would not be in the public interest. The proposed amendments would have allowed the use of the term "gold" in connection with jewelry items containing gold of less than 10-karat purity. Further, in July 1978, the Commission amended its Trade Practice Rules, to expressly prohibit the use of the term gold in such a context, since the previous rules prohibited the term only by implication.[3]

DOMESTIC PRODUCTION

Domestic mine production decreased in both 1978 and 1979 (tables 3-4). The main reason for the drop in output was the use of leaner ores, which became feasible as the price of gold rose. Average millhead grade at the Homestake mine dropped from 0.202 ounce per ton in 1977, to 0.180 ounce per ton in 1979. At the Carlin mine, the comparable figures were 0.302 and 0.186 ounce per ton. Contributing to the decline of output were the shutdown of one sizable gold mine for several months in 1978 while new reserves were blocked out, and the shutdown, by flooding, of a substantial byproduct producer for most of the 2-year period.

Table 3.—Mine production of gold in the United States, by State

(Troy ounces)

State	1975	1976	1977	1978	1979
Alaska	14,980	22,887	18,962	18,652	6,675
Arizona	85,790	102,062	90,167	92,989	101,840
California	9,606	10,392	5,704	7,480	3,195
Colorado	56,483	50,764	72,668	32,094	13,850
Idaho	2,529	2,755	12,894	20,492	24,140
Montana	17,259	24,075	22,348	19,967	24,050
Nevada	332,814	287,962	324,003	260,895	199,960
New Mexico	15,049	15,198	13,560	9,879	22,976
Oregon	W	28	675	340	W
South Dakota	304,935	318,511	304,846	285,512	245,912
Tennessee	W	W	13	W	--
Utah	189,620	187,318	210,501	235,929	260,916
Washington	W	W	24,006	W	W
Other States	24,187	26,085	--	14,603	16,269
Total	1,052,252	1,048,037	1,100,347	998,832	919,783

W Withheld to avoid disclosing company proprietary data; included in "Other States."

Table 4.—Mine production of gold in the United States, by month

(Troy ounces)

Month	1975	1976	1977	1978	1979
January	88,441	91,121	90,768	82,304	72,239
February	82,358	82,215	81,705	89,695	69,245
March	75,739	88,096	93,498	87,198	76,000
April	86,234	91,488	87,294	89,196	75,653
May	88,252	93,317	94,166	81,305	76,590
June	91,578	87,760	86,924	84,701	76,980
July	75,787	83,776	82,238	69,119	80,013
August	84,302	84,971	93,690	83,502	82,930
September	94,255	88,727	85,855	85,600	79,077
October	93,667	93,195	99,402	94,090	82,356
November	95,908	81,377	101,034	80,506	76,148
December	95,731	81,994	103,773	71,616	72,552
Total	1,052,252	1,048,037	1,100,347	998,832	919,783

Approximately two-thirds of domestic gold mine output was accounted for by three mines - Utah Copper (Bingham Canyon), Homestake, and Carlin.

The 25 largest mines (tables 5-6) accounted for 96% of domestic production in 1978 and 97% in 1979. Byproduct production from mines among the top 25 declined only 2% during the 2-year period, while production from precious metal ores in the top 25 mines decreased 23%.

Gold production in 1978 (1979 figures in parentheses) was reported by 171 (154) mines, of which 37 (23) were placer mines, 32 (39) were lode mines producing from precious metal ores, and 102 (92) were lode byproduct producers. About 58% (55%,) of the gold came from precious metal ores, 40% (44%) from base metal ores, and 2% (1%) from placers (figure 1, tables 7-8). The methods by which gold was extracted from its ores reflected the nature of the ores; thus, most of the gold was recovered by cyanidation of precious metal ores, and by smelting of base metal ores, while minor quantities were recovered by amalgamation and by gravity methods (tables 9-11). The average recovery grade of gold ores mined in lode gold mines was 0.12 (0.08) ounce per ton, while placer mines averaged 0.015 (0.009) ounce per cubic yard of gravel washed.

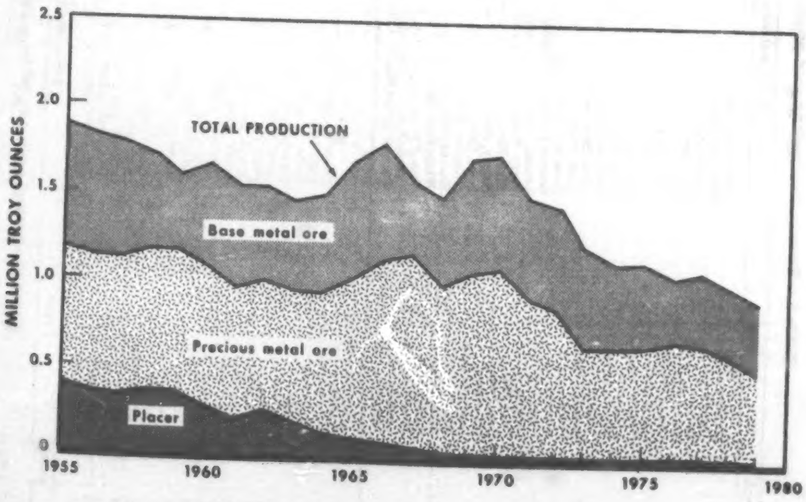


Figure 1.—Gold mined in the United States.

Table 5.—Twenty-five leading gold-producing mines in the United States in 1978, in order of output

Rank	Mine	County and State	Operator	Source of gold
1	Homestake	Lawrence, S. Dak	Homestake Mining Co	Gold ore.
2	Utah Copper	Salt Lake, Utah	Kennecott Copper Corp	Copper ore.
3	Carlin	Eureka, Nev	Carlin Gold Mining Co	Gold ore.
4	Round Mountain	Nye, Nev	Smokey Valley Mining Corp	Do.
5	Copper Canyon	Lander, Nev	Duval Corp	Copper ore.
6	San Manuel	Pinal, Ariz	Magma Copper Co	Do.
7	Magma	do	do	Do.
8	Sunnyside	San Juan, Colo	Standard Metals Corp	Lead-zinc ore.
9	New Cornelia	Pima, Ariz	Phelps Dodge Corp	Copper ore.
10	Delamar	Owyhee, Idaho	Earth Resources Co	Gold-silver ore.
11	Berkeley Pit	Silver Bow, Mont	The Anaconda Company	Copper ore.
12	Trixie	Utah, Utah	Kennecott Copper Corp	Gold-silver ore.
13	Morenci	Greenlee, Ariz	Phelps Dodge Corp	Copper ore.
14	Nome Unit	Seward Peninsula, Alaska	Alaska Gold Co	Placer.
15	Atlanta	Lincoln, Nev	Standard Slag Co	Gold ore.
16	Knob Hill	Ferry, Wash	Day Mines, Inc	Do.
17	Bootstrap	Elko, Nev	Carlin Gold Mining Co	Do.
18	Gooseberry	Storey, Nev	West Coast Oil & Gas Corp	Do.
19	Leadville Unit	Lake, Colo	ASARCO Incorporated	Lead-zinc ore.
20	Metcalf	Greenlee, Ariz	Phelps Dodge Corp	Copper ore.
21	Windfall	Eureka, Nev	Idaho Mining Co	Gold ore.
22	Ruth Pit	White Pine, Nev	Kennecott Copper Corp	Copper ore.
23	Pinto Valley	Gila, Ariz	Cities Service Co	Do.
24	Center	Grant, N. Mex	Dresser Industries, Inc	Gold ore.
25	Idarado	Ouray and San Miguel, Colo	Idarado Mining Co	Copper-lead-zinc ore.

Table 6.—Twenty-five leading gold-producing mines in the United States in 1979, in order of output

Rank	Mine	County and State	Operator	Source of gold
1	Utah Copper	Salt Lake, Utah	Kennecott Copper Corp	Copper ore.
2	Homestake	Lawrence, S. Dak	Homestake Mining Co	Gold ore.
3	Carlin	Eureka, Nev	Carlin Gold Mining Co	Do.
4	Round Mountain	Nye, Nev	Smokey Valley Mining Corp	Do.
5	San Manuel	Pinal, Ariz	Magma Copper Co.	Copper ore.
6	Magma	do	do	Do.
7	Berkeley Pit	Silver Bow, Mont	The Anaconda Company	Do.
8	Delamar	Owyhee, Idaho	Earth Resources Co	Gold-silver ore.
9	New Cornelia	Pima, Ariz	Phelps Dodge Corp	Copper ore.
10	Morenci	Greenlee, Ariz	do	Do.
11	Knob Hill	Ferry, Wash	Day Mines, Inc	Gold ore.
12	Gooseberry	Storey, Nev	West Coast Oil & Gas Corp	Do.
13	Leadville Unit	Lake, Colo	ASARCO Incorporated	Lead-zinc ore.
14	Trixie	Utah, Utah	Kennecott Copper Corp	Gold-silver ore.
15	Atlanta	Lincoln, Nev	Standard Slag Co	Gold ore.
16	Chino	Grant, N. Mex	Kennecott Copper Corp	Copper ore.
17	Bootstrap	Elko, Nev	Carlin Gold Mining Co	Gold ore.
18	Continental	Grant, N. Mex	UV Industries, Inc	Copper ore.
19	Tyrone	do	Phelps Dodge Corp	Do.
20	Pinto Valley	Gila, Ariz	Cities Service Co	Do.
21	Sacaton Unit	Pinal, Ariz	ASARCO Incorporated	Do.
22	Windfall	Eureka, Nev	Idaho Mining Co	Gold ore.
23	Nome Unit	Seward Peninsula, Alaska	Alaska Gold Co	Placer.
24	Summit Mountain	Grant, N. Mex	Summit Minerals, Inc	Gold-silver ore.
25	Metcalf	Greenlee, Ariz	Phelps Dodge Corp	Copper ore.

Table 7.—Gold produced in the United States in 1978, by State, type of mine, and class of ore

State	Placer (troy ounces of gold)	Lode							
		Gold ore		Gold-silver ore		Silver ore		Copper ore	
		Short tons	Troy ounces of gold	Short tons	Troy ounces of gold	Short tons	Troy ounces of gold	Short tons	Troy ounces of gold
Alaska	18,599	35	18	W	W	--	--	--	--
Arizona	--	--	--	--	--	3,449	33	139,806,789	92,507
California	3,559	15,323	3,227	W	W	--	--	--	--
Colorado	W	W	W	5,982	797	W	W	--	--
Idaho	--	82	75	W	W	794,486	2,219	--	--
Montana	44	41,191	1,200	5,636	1,221	80,858	544	17,889,635	16,949
Nevada	W	2,593,102	228,991	14	6	1,050	12	W	W
New Mexico	--	W	W	10,282	1,214	--	--	W	W
Oregon	--	2,470	340	--	--	--	--	--	--
South Dakota	--	1,590,406	285,512	--	--	--	--	--	--
Other States[1]	89	49,761	15,205	715,688	35,800	111,896	1,167	54,181,706	257,703
Total	22,291	4,292,370	534,568	737,602	39,038	991,739	3,975	211,878,130	367,159
Percent of total gold	2	XX	54	XX	4	XX	(2)	XX	37

State	Lode						Total[3]	
	Lead and zinc ores		Copper-lead, lead-zinc, copper-zinc, and copper-lead-zinc ores		Old tailings, etc.			
	Short tons	Troy ounces of gold	Short tons	Troy ounces of gold	Short tons	Troy ounces of gold	Short tons	Troy ounces of gold
Alaska	--	--	--	--	W	W	53	18,652
Arizona	25	1	--	--	46,402	448	139,856,665	92,989
California	--	--	--	--	W	W	17,065	7,480
Colorado	40	4	510,977	30,045	--	--	624,398	32,094
Idaho	W	W	859,860	767	--	--	2,294,553	20,492
Montana	--	--	65	9	--	--	18,017,385	19,967
Nevada	--	--	87,758	39	--	--	5,166,857	260,895
New Mexico	W	W	--	--	--	--	15,638,930	9,879

Oregon	--	--	--	--	--	--	2,470	340
South Dakota	--	--	--	--	--	--	1,590,406	285,512
Other States[1]	48,151	106	2,128,338	232	14	[4]150	38,372,689	250,532
Total	48,216	111	3,586,998	31,092	46,416	598	221,581,471	998,832
Percent of total gold	XX	([2])	XX	3	XX	([2])	XX	100

W Withheld to avoid disclosing company proprietary data; included in "Other States." XX Not applicable.

[1] Includes Tennessee, Texas, Utah, Washington and items indicated by symbol W.

[2] Less than 1/2 unit.

[3] Data may not add to State totals because of items withheld to avoid disclosing individual company proprietary data.

[4] Includes byproduct gold recovered from tungsten ore in California.

Table 8.—Gold produced the United States in 1979, by State, type of mine, and class of ore

State	Placer (troy ounces of gold)	Lode							
		Gold ore		Gold-silver ore		Silver ore		Copper ore	
		Short tons	Troy ounces of gold	Short tons	Troy ounces of gold	Short tons	Troy ounces of gold	Short tons	Troy ounces of gold
Alaska	6,675	--	--	--	--	--	--	--	--
Arizona	--	80,521	1,794	--	--	W	W	159,750,391	99,542
California	W	9,384	2,060	2,037	714	--	--	--	--
Colorado	W	--	--	6,410	574	108,642	1,206	--	--
Idaho	--	W	W	W	W	775,298	2,583	--	--
Montana	W	285	170	3,633	259	78,055	2,007	17,122,259	21,356
Nevada	12	4,523,166	199,733	W	W	W	W	W	W
New Mexico	12	1,730	567	13,486	3,112	--	--	27,122,254	19,284
South Dakota	--	1,429,886	245,912	--	--	--	--	--	--
Other States[1]	348	45,742	16,241	730,654	30,525	294	20	37,896,858	251,309
Total	7,047	6,090,714	466,477	756,220	35,184	962,289	5,816	241,893,762	391,491
Percent of total gold	1	XX	51	XX	4	XX	1	XX	42

State	Lode						Total[2]	
	Lead and zinc ores		Copper-lead, lead-zinc, copper-zinc, and copper-lead-zinc ores		Old tailings, etc.			
	Short tons	Troy ounces of gold	Short tons	Troy ounces of gold	Short tons	Troy ounces of gold	Short tons	Troy ounces of gold
Alaska	--	--	--	--	--	--	--	6,675
Arizona	W	W	--	--	37,491	490	159,868,974	101,840
California	--	--	--	--	--	W	11,421	3,195
Colorado	W	W	180,236	11,899	W	W	295,302	13,850
Idaho	673	80	821,649	550	--	--	2,288,784	24,140
Montana	12,762	196	188	48	W	W	17,217,287	24,050
Nevada	--	--	--	--	--	--	4,562,709	199,960
New Mexico	192	1	--	--	--	--	27,137,662	22,976

South Dakota	--	--	--	--	--	--	1,429,886	245,912
Other States[1]	3,365,294	157	--	--	5,002	[4]347	41,314,547	277,185
Total	3,379,021	434	1,002,073	12,497	42,493	837	254,126,572	919,783
Percent of total gold	XX	([2])	XX	1	XX	([2])	XX	100

W Withheld to avoid disclosing company proprietary data; included in "Other States." XX Not applicable.

[1] Includes Missouri, Oregon, Utah, Washington, and States indicated by symbol W.

[2] Less than 1/2 unit.

[3] Data may not add to State totals because of items withheld to avoid disclosing company proprietary data.

[4] Includes byproduct gold recovered from tungsten ore in California.

Table 9.—Gold produced in the United States from ore, old tailings, etc., by State and method of recovery

State	Total ore, old tailings, etc., treated[1] (thousand short tons)	Ore and old tailings to mills					Crude ore, old tailings, etc., to smelters[1]	
		Thousand short tons[1]	Recoverable in bullion		Concentrates smelted and recoverable metal			
			Amalgamation (troy ounces)	Cyanidation (troy ounces)	Concentrates (short tons)	Troy ounces	Thousand short tons	Troy ounces
1978:								
Alaska	(2)	(2)	--	--	1	18	(2)	35
Arizona	178,895	178,000	--	--	3,112,494	92,459	895	530
California	[3]17	[3]17	1,337	6	3,095	2,376	(2)	202
Colorado	809	800	908	--	81,450	30,361	9	743
Idaho	2,394	2,393	9	17,371	153,166	2,921	1	191
Montana	[4]18,022	[4]17,932	--	822	333,047	17,949	90	1,152
Nevada	[4]7,117	[4]7,083	--	228,956	75,422	31,775	34	157
New Mexico	21,920	21,818	--	--	660,674	4,557	102	5,322
Oregon	2	(2)	--	3	--	--	2	337
South Dakota	1,590	1,590	--	285,512	--	--	--	--
Utah	36,147	36,046	--	--	744,360	218,138	101	17,791
Other	5,881	5,881	--	--	263,497	14,601	(2)	2
Total	272,794	271,560	2,254	532,670	5,427,206	415,155	1,234	26,462
1979:								
Arizona	[4]204,463	[4]203,902	48	1,746	3,481,562	99,069	561	957
California	[3]12	[3]11	812	--	2,900	1,694	1	368
Colorado	393	382	374	--	39,554	12,555	11	898
Idaho	2,339	2,335	--	20,855	149,062	2,840	4	445
Montana	17,230	17,135	4	47	306,115	21,562	95	2,433
Nevada	[4]4,563	[4]4,563	--	199,724	937	155	(2)	69
New Mexico	27,161	27,062	--	--	920,305	19,284	99	3,680
South Dakota	1,430	1,430	--	245,912	--	--	--	--
Utah	37,905	37,859	--	--	83,826	250,965	46	9,951
Other	9,154	9,152	--	--	875,613	15,967	2	302
Total	304,650	303,831	1,238	468,284	5,859,874	424,111	819	19,103

[1] Includes some non-gold-bearing ores not separable.
[2] Less than 1/2 unit.
[3] Excludes tonnage of tungsten ore from which gold was recovered as a byproduct.
[4] Includes tonnages from which gold was recovered by heap leaching.

Table 10.—Gold produced at amalgamation and cyanidation mills in the United States and percentage of gold recovered from all sources

Year	Bullion and precipitates recovered (troy ounces)		Gold recovered from all sources (percent)			
	Amalgamation	Cyanidation	Amalgamation	Cyanidation	Smelting[1]	Placers
1975	13,783	617,330	1.3	58.7	38.1	1.9
1976	18,207	587,540	1.7	56.1	39.6	2.6
1977	26,615	597,633	2.4	54.3	41.2	2.1
1978	2,254	532,670	.2	53.3	44.3	2.2
1979	1,238	468,284	.1	50.9	48.2	.8

[1] Crude ores and concentrates.

Table 11.—Gold produced at placer mines in the United States, by method of recovery

Method and year	Mines producing	Washing plants	Material washed (thousand cubic yards)	Gold recoverable: Thousand troy ounces	Gold recoverable: Value (thousands)	Gold recoverable: Average value per cubic yard
Bucketline dredging:						
1975	4	5	[1]2,715	14	$2,314	$0.852
1976	3	4	[1]2,816	17	2,124	.754
1977	3	4	1,377	12	1,742	1.265
1978	2	3	1,010	11	2,187	2.164
1979	2	3	475	3	977	2.056
Dragline dredging:						
1975	6	6	210	3	469	2.229
1976	3	3	245	5	606	2.474
1977	7	7	[2]10	[3]2	311	[4]5.932
1978	9	9	[2]60	[3]3	519	[4]4.339
1979	3	3	86	1	347	4.019
Hydraulicking:						
1975	16	17	131	1	171	1.302
1976	14	14	129	1	157	1.212
1977	12	13	278	5	754	2.762
1978	10	10	233	4	784	3.367
1979	8	8	176	2	613	3.480
Nonfloating washing plants:						
1975	11	11	[2]--	[3]2	269	--
1976	25	26	[2]136	[3]4	560	[4]2.097
1977	7	7	[2]106	[3]3	477	[4]2.319
1978	11	11	[2]152	[3]4	812	[4]2.448
1979	7	8	[2]42	[3]1	225	[4]2.988
Underground placer, small-scale mechanical and hand methods, and suction dredge:						
1975	12	8	27	([5])	47	1.752
1976	4	4	2	([5])	15	8.881
1977	7	7	41	1	159	3.901
1978	5	5	1	([5])	13	13.431
1979	3	3	4	([5])	5	1.281
Total placers:						
1975	49	47	[1] [2]3,083	[3]20	[6]3,269	[4].973
1976	49	51	[1] [2]3,328	[3] [6]28	3,462	[4].958
1977	36	38	[2]1,807	[3]23	3,443	[4]1.638
1978	37	38	[2]1,456	[3]22	[6]4,314	[4]2.488
1979	23	25	[2] [6]784	[3]7	2,167	[4]2.639

[1] Does not include platinum-bearing material from which byproduct gold was recovered.
[2] Excludes tonnage of material treated at commercial sand and gravel operations recovering byproduct gold.
[3] Includes gold recovered at commercial sand and gravel operations.
[4] Gold recovered as a byproduct at sand and gravel operations not used in calculating average value per cubic yard.
[5] Less than 1/2 unit.
[6] Data do not add to total shown because of independent rounding.

Kennecott Copper Corp.'s Utah Copper (Bingham Canyon) mine, south of Salt Lake City, the largest copper mine in the United States, became also the country's largest gold producer in 1979, and was the second largest producer in 1978.

The Homestake mine, in the Black Hills, accounted for essentially all of South Dakota's gold output. As the grade of ore mined by Homestake decreased in response to higher prices, the mine's cost of production per ounce of gold climbed from $140 in 1977, to $176 in 1978, to $250 in 1979. To counter rising costs, Homestake was shifting away from cut-and-fill mining towards bulk mining methods, obtaining 29% of their production in 1979 by those methods. Ore reserves in 1979 were 16.9 million tons grading 0.211 ounce per ton.

Eight mines in Nevada were among the top 25 gold-producing mines in the country in 1978-79. They were the Carlin, Round Mountain, Copper Canyon, Atlanta, Bootstrap, Gooseberry, Windfall, and Ruth Pit (closed in 1978) mines. Output of the Carlin mine, north of Elko, decreased to 152,400 ounces in 1978, and to 133,000 ounces in 1979. Ore was mined from the Carlin, Blue Star, and Bootstrap pits; mining was completed at the latter in 1978, but ore was being heap-leached there in 1979. In April 1978, the new double-oxidation plant, developed to treat carbonaceous ores, was started up. By the end of 1979, drilling at the Les ore body, 14 miles south of the Carlin mill, had outlined 2.3 million tons of ore grading 0.157 ounce per ton, and an additional 3.1 million tons of lower grade ore which was to be tested to determine its amenability to heap leaching. Carlin's total reserves at yearend 1979, excluding the low-grade Les reserves, were 8.2 million tons grading 0.174 ounce per ton. Smokey Valley Mining Co.'s Round Mountain mine, north of Tonopah, increased output at its large heap leach, open pit operation by about one-third in 1978, moving closer to the design production of 55,000 ounces per year. Duval Corp.'s Copper Canyon mine, near Battle Mountain, was converted in 1978 from being primarily a copper producer to being primarily a gold producer. A substantial output in 1978 made Copper Canyon the seventh largest gold producer that year.

The Gooseberry mine of West Coast Oil & Gas Corp., east of Reno, appeared on the list of 25 leading mines in 1977, and by 1979 had climbed to 12th place on the list. Output at the Atlanta mine, north of Pioche, and at the Windfall mine, near Eureka, fell off somewhat in 1978-79. Kennecott Copper Corp.'s Ruth Pit copper mine, still a substantial producer of byproduct gold in 1978, was closed in April that year because of the depressed copper market.

Nearly all of Arizona's gold output came as a byproduct of the seven copper mines listed in tables 5-6.

In Colorado, the Sunnyside mine, near Silverton, producing gold from lead-zinc ore, was flooded out in June 1978. The Idarado mine, a byproduct gold producer at Ouray, was closed down in 1978 after nearly a century of operation.

The Delamar open pit silver-gold mine in southwestern Idaho opened a second pit in 1978, its second year of operation, which gave more flexibility in the ratio of gold to silver produced. The Knob Hill mine, at Republic, Wash., was closed for 6 months in 1978 while its new owner, Day Mines, Inc., explored for new reserves and rehabilitated the mill. New ore was successfully located, and the mill recommenced operation in August.

The rising price of gold in 1978-79 stimulated the search for gold in the Western States. Nevada, Idaho, Montana, and California attracted most of the exploration activity. There were about 3 dozen substantial deposits being explored, and about half of these entered the development or production stage during the 2-year period. The most important deposit appeared to be the Freeport Minerals-FMC Corp. deposit in Jerritt Canyon, Elko County, Nev. Similar in type and size to the Carlin deposit, 60 miles to the south, the Jerritt Canyon property was expected to come into production as a major gold mine by about 1982.

Refinery production of gold from old scrap grew substantially in both 1978 and 1979 (table 12). Production from new (manufacturer's) scrap, after increasing in 1978, dropped abruptly in the last 2 quarters of 1979, presumably because manufacturers were holding the scrap back as the price of gold rose precipitously. Less than one-fourth of refinery production was derived from domestic ores.

Table 12.—U.S. refinery production of gold

(Thousand troy ounces)

Source	1975	1976	1977	1978	1979
Concentrates and ores:					
Domestic	1,093	954	956	962	795
Foreign	250	123	62	71	83
Old scrap[1]	1,122	1,068	1,040	1,384	1,689
New scrap	1,574	1,436	1,414	1,701	1,209
Total	4,039	3,581	3,472	4,118	3,776

[1] Excludes upgrading of U.S. Government-owned gold (mostly coin gold) by the U.S. Assay Office, amounting to 316,137 ounces in 1977, 2,386,874 ounces in 1978, and 3,000,068 ounces in 1979.

CONSUMPTION

Domestic consumption of refined gold, as measured by its conversion into fabricated and semifabricated forms, declined slightly in 1978-79 (figure 2, table 13). As in recent years, jewelry accounted for about 56% of consumed gold, industrial uses for nearly 30%, and dental uses for about 13%. The rapidly rising gold price in 1979 had only a modest effect on consumption, as users worked down their inventories of refined gold. However, it lent impetus to efforts to reduce the quantities of gold used in manufactured items. Thus, electronics manufacturers were substituting palladium, tin, and other suitable metal for gold where possible, and jewelry makers were reportedly beginning to shift away from karat golds to gold-filled, rolled gold, gold plated, and gold-silver combinations.

Although data are not reported on the purchase or "consumption" of gold bullion by the private sector, the quantities purchased annually are believed to be represented approximately by the sizable supply surpluses that have occurred each year since 1975, when the right of U.S. citizens to own gold bullion was reinstated. In 1975, the supply surplus was 520,000 ounces, and reached 2.4 million ounces in 1976, 2.7 million ounces in 1977, and 4.1 million ounces in 1978 and again in 1979. Also, the flow of gold coins, mostly "bullion coins," into the United States has been substantial since the purchase of nonnumismatic coins in quantity was authorized in 1974. Estimated imports of gold coins, in millions of ounces, were: 1974, 3.1; 1975, 1.7; 1976, 1.3; 1977, 1.6; 1978, 3.7; 1979, 2.8.

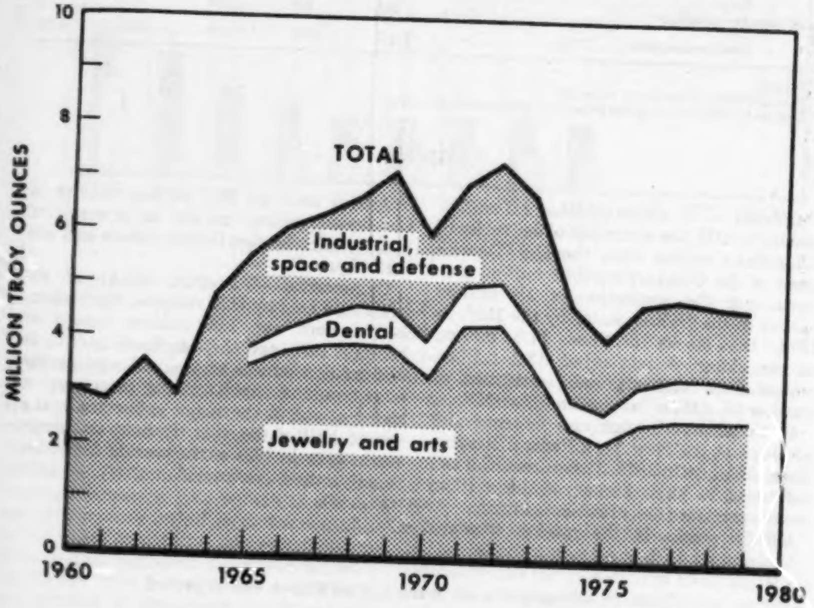


Figure 2.—Fabrication of gold in the United States.

Table 13.—U.S. fabrication of gold, by end use

(Thousand troy ounces)

End use	1975	1976	1977	1978	1979
Jewelry and arts:					
Karat gold	1,747	2,153	2,236	2,224	2,256
Fine gold for electroplating	31	29	37	42	32
Gold filled and other	302	380	385	385	361
Total	2,080	2,562	2,658	2,651	2,649
Dental	595	694	728	706	612
Industrial:					
Karat gold	39	56	60	64	64
Fine gold for electroplating	592	686	656	687	797
Gold filled and other	428	491	r494	562	542
Total	1,059	1,233	r 2 1,209	1,313	1,403
Small items for investment[1]	258	159	268	68	45
Total consumption	2 3,993	4,648	r 2 4,863	4,738	4,708

rRevised.

[1] Fabricated bars, medallions, coins, etc.

[2] Data do not add to total shown because of independent rounding.

STOCKS

Official.—U.S. stocks declined 1.0 million ounces in 1978, the net result of deliveries of 2.5 million ounces from the U.S. Department of the Treasury's public bullion auctions, and the restitution of 1.4 million ounces to the United States by the IMF. In 1979, the stocks declined 11.8 million ounces, after deliveries of 13.2 million ounces from auctions, and restitution of another 1.4 million ounces from the IMF.

Gold held for foreign and international accounts at the New York Federal Reserve Bank declined in 1978-79 as a result of net deliveries to the market of 1.6 million ounces and transfers of bullion abroad.

Official stocks in the market economy countries declined 28.3 million ounces in the 2-year period, mainly as a result of bullion sales by the United States and the IMF (figure 3).

Commercial.—Industrial stocks of refined gold held by U.S. refiners, fabricators, and dealers was 1.66 million ounces at yearend 1978, and then declined in 1979 to 0.96 million ounces at yearend, apparently as a result of rapidly rising prices and a strike at one of the major refineries in the second half of the year. Futures exchange stocks grew in 1978 as the market expanded rapidly, then contracted slightly in 1979 (table 14).

Table 14.—Stocks of gold in the United States, end of period

(Thousand troy ounces)

	1975	1976	1977	1978	1979
Treasury Department[1]	274,728	274,704	277,570	276,432	264,614
Industry	788	928	1,976	1,672	947
Futures exchange	530	320	1,835	2,752	2,473
Earmarked gold[2]	396,613	388,773	378,683	366,248	359,286

[1] Includes gold in Exchange Stabilization Fund.

[2] Gold held for foreign and international official accounts at New York Federal Reserve Bank.

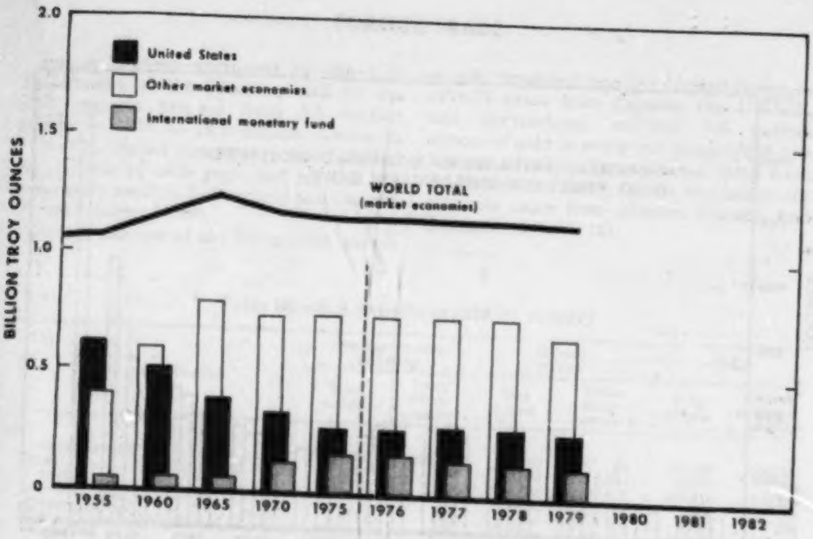


Figure 3.—World monetary gold stocks.

PRICE

The price of refined gold (table 15, figure 4) increased fairly steadily in 1978 and the first quarter of 1979, then began to accelerate upwards until yearend 1979 when it reached the $500 per troy ounce level. The substantial rise in the world price was ascribed by gold market observers to continuing purchase of gold bullion as a hedge against currency inflation, and was said to reflect unstable political and economic conditions. The high gold price stimulated a search for new ore deposits and the reexamination of abandoned mines and tailings dumps, but on the other hand, did not inhibit consumption in the United States appreciably. By the end of 1979, however, the high and rapidly rising price (together with the high interest rates then prevailing) was creating financial difficulties for some U.S. gold users, especially the manufacturers of jewelry.

The second amendment to the IMF articles of agreement, ratified on March 30, 1978, abolished the official IMF price for gold. By the end of 1979, many of the industrialized nations had adopted market-related prices for valuation of their bullion reserves, leaving the United States as the only holder of large gold stocks still valuing its bullion at a fixed price ($42.22 per ounce).

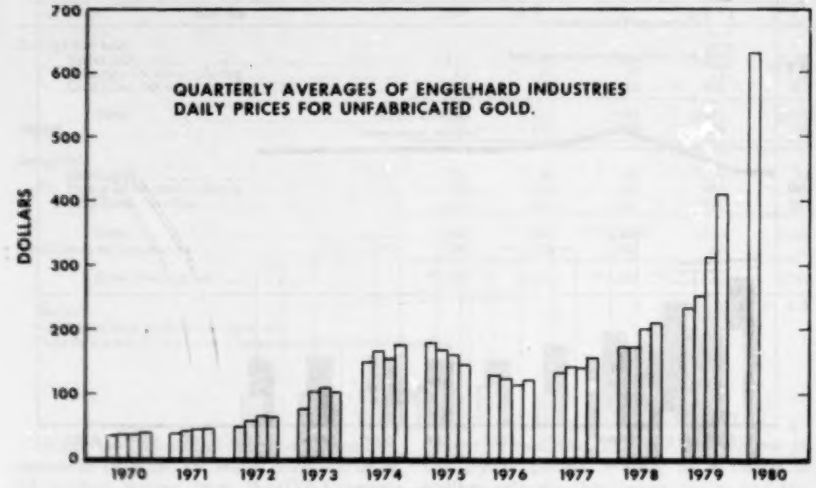


Figure 4.—U.S. gold prices.

Table 15.—U.S. monthly gold prices[1]

(Dollars per troy ounce)

Month	1978			1979		
	Low	High	Average	Low	High	Average
January	166.20	178.00	173.69	217.15	236.40	227.57
February	173.35	183.70	178.59	229.65	252.65	245.84
March	177.80	190.50	184.05	238.45	249.10	242.35
April	168.15	183.90	175.78	232.20	245.60	239.12
May	169.40	184.65	176.49	246.60	274.90	257.64
June	180.85	186.80	184.06	273.20	284.15	279.37
July	183.50	201.60	189.27	281.65	306.10	295.57
August	198.30	216.05	206.30	283.00	319.45	301.67
September	205.95	218.70	212.41	325.40	397.60	357.17
October	217.40	243.05	227.69	372.35	426.40	391.99
November	193.70	227.80	206.20	373.10	415.95	392.64
December	194.95	226.30	208.13	426.75	517.00	459.04
Year	166.20	243.05	193.55	217.15	517.00	307.50

[1] Engelhard Industries daily quotation.

FOREIGN TRADE

Fed by bullion auctioned by the U.S. Department of the Treasury and by the IMF, exports jumped from 5.5 million ounces in 1978 to 16.5 million ounces in 1979. The United Kingdom received 43% of the exports in each year, and most of the remainder went to Switzerland and Canada (figure 5, tables 17-18).

Ninety percent of the 9.3 million ounces of gold imported into the United States in 1978-79 came from Canada, the U.S.S.R., and Switzerland. Another 6.5 million ounces of gold in coins was imported in the 2 years, of which three-fourths came from the Republic of South Africa, and important amounts came from Mexico, Canada, and Switzerland (table 16).

Table 16.—U.S. exports of gold, by country

Year and destination	Ore, base bullion, and scrap		Refined bullion		Total	
	Troy ounces	Value (thousands)	Troy ounces	Value (thousands)	Troy ounces	Value (thousands)
1978:						
Belgium-Luxembourg	144,256	$25,298	13	$2	144,269	$25,300
Brazil	1,639	309	13,333	2,594	14,972	2,903
Canada	32,702	5,968	654,108	139,656	686,810	145,624
Ecuador	--	--	1,980	413	1,980	413
France	1,025	162	860	166	1,885	328
Germany, Federal Republic of	9,062	1,885	975,064	233,029	984,126	234,914
Hong Kong	1,258	191	8	1	1,266	192
Italy	224	40	8,033	1,697	8,257	1,737
Japan	72,004	12,897	83,342	16,254	155,346	29,151
Mexico	80	14	347,949	65,003	348,029	65,017
Netherlands	160	37	428,574	75,709	428,734	75,746
Paraguay	--	--	2,501	469	2,501	469
Singapore	876	134	40	12	916	146
Spain	9,661	1,922	34	5	9,695	1,927
Sweden	11,477	2,149	7	1	11,484	2,150
Switzerland	34,596	6,693	287,733	55,483	322,329	62,176
Taiwan	216	34	40,102	8,722	40,318	8,756
United Kingdom	165,491	31,101	2,176,503	424,934	2,341,994	456,035
Venezuela	12	3	3,524	633	3,536	636
Other	280	45	763	129	1,043	174
Total	485,019	88,882	5,024,471	1,024,912	5,509,490	1,113,794
1979:						
Argentina	--	--	1,616	567	1,616	567
Belgium-Luxembourg	93,680	28,644	72,651	18,650	166,331	47,294
Brazil	11,053	2,627	24,805	7,828	35,858	10,455
Canada	300,580	101,974	2,303,588	814,059	2,604,168	916,033
Costa Rica	--	--	1,088	226	1,088	226
Ecuador	--	--	3,308	996	3,308	996
El Salvador	122	20	673	125	795	145
France	3,176	875	68,810	19,760	71,986	20,635
Germany, Federal Republic of	17,325	5,808	222,675	70,975	240,000	76,783
Italy	200	56	9,994	2,670	10,194	2,726
Japan	29,840	7,421	111,267	28,313	141,107	35,734
Mexico	1,667	512	679,140	216,976	680,807	217,488
Netherlands	36	8	382,873	125,058	382,909	125,066
Panama	100	22	843	161	943	183
Philippines	--	--	3,214	629	3,214	629
Spain	26,125	6,912	--	--	26,125	6,912
Sweden	8,203	2,547	--	--	8,203	2,547
Switzerland	9,558	2,372	4,996,472	1,432,743	5,006,030	1,435,115
United Kingdom	399,149	127,428	6,706,909	1,880,550	7,106,058	2,007,978
Other	653	135	1,006	217	1,659	352
Total	901,527	297,361	15,589,872	4,620,503	16,491,399	4,907,864

Table 17.—U.S. imports for consumption of gold, by country

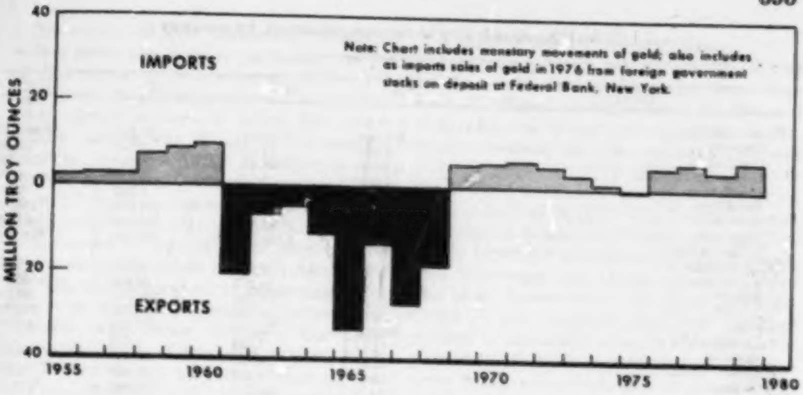
Country	Ore, base bullion, and scrap: Troy ounces	Ore, base bullion, and scrap: Value (thousands)	Refined bullion: Troy ounces	Refined bullion: Value (thousands)	Total: Troy ounces	Total: Value (thousands)
1978:						
Argentina	5,792	$1,061	10,887	$1,953	16,679	$3,014
Australia	1,105	230	230	46	1,335	276
Austria	--	--	72,229	13,475	72,229	13,475
Brazil	--	--	1,608	322	1,608	322
Canada	118,436	22,360	1,641,636	316,901	1,760,072	339,261
Chile	206	41	46,628	8,857	46,834	8,898
Dominican Republic	4,980	983	19,569	4,100	24,549	5,083
Germany, Federal Republic of	5,880	1,080	57	8	5,937	1,088
Guyana	1,402	252	166	30	1,568	282
Hong Kong	3,491	644	43	10	3,534	654
Japan	--	--	123,336	23,640	123,336	23,640
Korea, Republic of	2,236	370	--	--	2,236	370
Malaysia	8,100	1,524	--	--	8,100	1,524
Mexico	11,831	2,113	4,922	890	16,753	3,003
Nicaragua	22,481	4,056	8,817	1,662	31,298	5,718
Peru	11,765	2,279	26,494	5,020	38,259	7,299
Philippines	1,510	300	--	--	1,510	300
Singapore	10,643	2,051	--	--	10,643	2,051
South Africa, Republic of	6,476	1,022	964	215	7,440	1,237
Switzerland	17,241	3,276	950,396	177,484	967,637	180,760
U.S.S.R	4,592	844	1,451,109	285,793	1,455,701	286,637
United Kingdom	1,893	369	46,566	9,778	48,459	10,147
Yugoslavia	--	--	38,965	7,084	38,965	7,084
Other	2,687	446	2,356	455	5,043	901
Total	242,747	45,301	4,446,978	857,723	4,689,725	903,024
1979:						
Argentina	3,149	868	2,199	570	5,348	1,438
Australia	3,626	860	134	39	3,760	899
Canada	94,692	31,753	1,694,963	533,391	1,789,655	565,144
Chile	29,044	8,250	41,340	12,846	70,384	21,096
Costa Rica	--	--	1,319	507	1,319	507
Dominican Republic	6,429	1,966	25,543	6,423	31,972	8,389
France	51	20	1,236	398	1,287	418
Germany, Federal Republic of	1,309	305	703	223	2,012	528
Guyana	2,152	626	3,360	1,191	5,512	1,817
Hong Kong	11,505	3,540	1,361	443	12,866	3,983
Ireland	3,267	653	--	--	3,267	653
Israel	2,629	1,124	--	--	2,629	1,124
Italy	165	67	1,926	586	2,091	653
Japan	--	--	94,659	27,649	94,659	27,649
Korea, Republic of	2,534	628	--	--	2,534	628
Malaysia	8,200	2,251	--	--	8,200	2,251
Mexico	9,918	2,874	1,210	337	11,128	3,211
Netherlands	--	--	8,028	2,975	8,028	2,975
Nicaragua	14,548	2,867	7,507	1,757	22,055	4,624
Peru	10,608	3,018	22,421	5,892	33,029	8,910
Philippines	22,815	7,593	--	--	22,815	7,593
Singapore	8,220	2,308	--	--	8,220	2,308
South Africa, Republic of	520	231	9,350	2,347	9,870	2,578
Switzerland	16,166	6,267	739,944	234,577	756,110	240,844
U.S.S.R	1,378	493	1,644,195	548,339	1,645,573	548,832
United Kingdom	656	255	29,018	7,751	29,674	8,006
Yugoslavia	--	--	41,168	11,683	41,168	11,683
Other	2,315	717	2,218	745	4,533	1,462
Total	255,896	79,534	4,373,802	1,400,669	4,629,698	1,480,203

Table 18.—Value of U.S. gold trade

(Thousand dollars)

Year	Exports	Imports[1]
1975	492,932	456,638
1976	375,048	331,018
1977	1,112,711	674,085
1978	1,113,794	903,024
1979	4,987,864	1,480,203

[1] Value of general imports for 1975-77. Value of imports for consumption for 1978-79; values of general imports were $921,504,188 (1978) and $1,506,716,888 (1979).



Note: Chart includes monetary movements of gold; also includes as imports sales of gold in 1976 from foreign government stocks on deposit at Federal Bank, New York.

Figure 5.—Net U.S. trade in gold.

WORLD REVIEW

World gold mine production remained at about 39 million ounces in 1978, and again in 1979. Continuing high gold prices stimulated modest increases in production in several countries; on the other hand, production in the United States and a few other countries decreased somewhat because mines were enabled to use leaner ores as the price of gold increased. The pattern of production remained essentially unchanged, with the Republic of South Africa accounting for about 58% of output, the U.S.S.R. for 20%, Canada for 4%, the United States for 2%, and 61 other countries for the remaining 16% (figure 6, table 19).

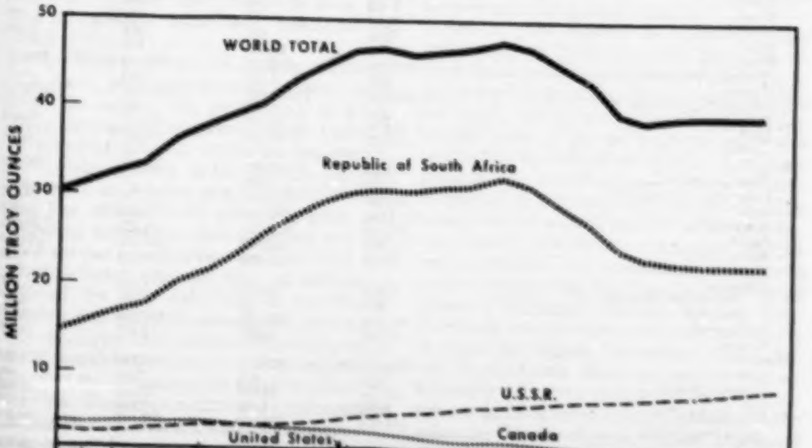


Figure 6.—Gold: World mine production.

Table 19.—Gold: World mine production, by country

(Troy ounces)

Country[1]	1976	1977	1978[p]	1979[e]
North America:				
Canada	1,691,806	1,733,609	1,735,077	[2]1,561,013
Costa Rica[e]	9,600	12,200	15,900	15,000
Dominican Republic	413,788	348,473	336,073	330,000
El Salvador	3,007	2,156	3,619	4,000
Honduras	2,280	2,481	[e]2,500	2,500
Mexico	162,811	212,709	202,003	[2]188,000
Nicaragua	[r]75,841	65,764	[e]65,800	60,000
United States	1,048,037	1,100,347	998,832	[2]919,783
South America:				
Argentina	5,804	5,500	5,514	5,500
Bolivia	41,540	24,277	24,660	[2]30,319
Brazil[3]	239,520	279,520	304,110	340,200
Chile	[r]129,172	116,376	102,416	105,000
Colombia	300,307	263,437	257,632	290,000
Ecuador	[r]11,014	7,649	3,213	3,500
French Guiana	2,797	4,823	[e]5,000	5,000
Guyana	[r]15,656	11,899	15,396	[2]10,593
Peru	[r]79,412	104,393	103,069	[2]122,333
Surinam	39	[r]376	--	--
Venezuela	16,506	17,403	11,960	14,000
Europe:				
Finland	26,299	27,392	29,096	[2]28,325
France	61,022	50,444	59,640	60,000
Germany, Federal Republic of	2,456	2,392	2,119	2,400
Hungary[e]	155,000	115,000	60,000	60,000
Portugal	[r]10,031	8,830	7,765	[2]10,706
Romania[e]	60,000	65,000	65,000	65,000
Spain	148,601	117,800	[e]150,000	155,000
Sweden	62,179	67,934	76,294	[2]70,000
U.S.S.R.[e]	7,700,000	7,850,000	8,000,000	8,160,000
Yugoslavia	157,088	164,226	165,000	140,000
Africa:				
Burundi	426	[e]450	[e]450	450
Cameroon	251	182	200	200
Central African Empire	[e]400	[e]100	965	500
Congo[e]	[r]6,900	[r]7,000	7,000	7,000
Ethiopia	[r]11,253	7,725	[3]8,000	8,100
Gabon	3,086	2,572	965	100
Ghana	532,473	480,884	402,034	[2]482,300
Kenya	37	89	205	200
Madagascar	[e]160	76	125	125
Mali[e]	[r]900	932	965	1,000
Mauritania	22,120	28,000	8,000	--
Rhodesia, Southern[e]	600,000	600,000	640,000	700,000
Rwanda	936	1,814	1,125	1,100
South Africa, Republic of	22,935,988	22,501,886	22,648,558	[2]22,616,656
Tanzania	10	28	12	10
Zaire	91,093	80,418	76,077	75,000
Zambia	10,955	[r] [e]11,250	8,457	7,941
Asia:				
China, mainland[e]	[r]80,000	[r]100,000	150,000	200,000
Democratic Kampuchea[e]	1,000	1,000	--	--
India[4]	100,696	[r]96,902	87,579	[2]84,749
Indonesia[5]	[r]114,000	[r]82,300	81,600	70,000
Japan	137,669	149,018	145,225	[2]132,879
Korea, North[e]	160,000	[r]160,000	160,000	160,000
Korea, Republic of[4]	18,744	21,380	27,392	[2]23,566
Malaysia:				
Peninsular Malaysia	3,574	4,172	5,805	5,000
Sarawak	[r]964	742	971	1,000
Philippines	501,210	558,235	586,598	[2]546,536
Taiwan	26,952	14,995	13,407	15,000
Oceania:				
Australia	502,741	630,155	647,580	[2]588,359
Solomon Islands	[e]600	372	[e]400	400
Fiji	65,757	49,067	28,065	25,000
New Zealand	3,276	7,168	7,044	7,000
Papua New Guinea	668,014	739,730	751,265	700,000
Total	[r]39,233,798	39,121,056	39,303,757	39,238,343

[e] Estimate. [p] Preliminary. [r] Revised.

[1] Gold is also produced in Bulgaria, Burma, Czechoslovakia, the German Democratic Republic, Guinea, Norway, Thailand, and several other countries. However, available data are insufficient to make reliable output estimates. The previous edition of this table listed Angola, Liberia, Nigeria, and Sudan as gold producers but output of these countries for 1976-77 has been revised to zero.

[2] Reported figure.

[3] Series revised to include an estimate of unregistered output by small producers.

[4] Refinery output.

[5] Excludes production from so-called "people's mines."

The supply of gold (excluding most secondary gold), available to purchasers in the market economy countries in 1978 (1979 figures are in parentheses) was about 54.0 (56.5) million ounces, of which 30.7 (30.4) million ounces was mined in the market economy countries, 13.2 (7.4) million ounces came from central economy countries, and 10.1 (18.7) million ounces from net "official" sales, mainly the IMF and U.S. Treasury auctions. As in former years, most of the gold from the Republic of South Africa, the U.S.S.R., and several other producing countries was funneled through Switzerland, England, and other Western European countries. Much of the gold flowing from the United States to Europe was bullion sold from IMF and U.S. Treasury stocks.

Demand for gold remained strong in 1978 and most of 1979 in spite of the rising price and the injection of large quantities of monetary bullion into the market. Apparently, private investors, and some governments, bought gold for its traditional functions as a store of value and a hedge against inflation of currency. The distribution of gold in 1978 was reported as follows:[4] 89% of the gold was fabricated (about two-thirds of it in the developed countries), and 11% was purchased as bullion. About 64% of the fabricated gold went into jewelry, 17% into coins, 6% into dental uses, 5% into electronics, 5% into other industrial uses, and 3% into medals, medallions, and unofficial coins.

The Group of Ten (10 leading industrial countries, plus Switzerland) allowed its 2-year old agreement, prohibiting members from buying gold at prices higher than the official IMF price, to expire on January 31, 1978. Subsequently, in March 1978, the IMF amended its articles of agreement, abolishing the official IMF price for gold, and allowing member countries to buy and sell gold on the free market. In June 1978, the IMF reduced the quantity of bullion it offered for sale each month to 470,000 ounces, from 525,000 ounces, and gave member countries the option of buying gold at each monthly auction on a noncompetitive basis at the average price established in the auction. The latter option was continued for 1 year during which 1.5 million ounces was sold to member countries. In June 1979, the IMF again reduced its monthly bullion offering, to 444,000 ounces. The 4-year program of monthly auctions, during which 25 million ounces were sold, was scheduled to end in May 1980.

A brief review, by country follows:

Australia.—Most of the gold mined in Australia in 1978-79 came from four sources. Three of these were in Western Australia; the largest was the Telfer mine, which produced 228,000 ounces in 1978 and 172,000 ounces in 1979. The Mt. Charlotte mine yielded 101,000 ounces in 1978 and 109,000 ounces in 1979. The Central Norseman mine's production was in the range of 85,000 to 90,000 ounces each of the 2 years. The Warrengo and Gecko mines of Peko Wallsend Operations Ltd., near Tennant Creek in the Northern Territory, together yielded in the order of 100,000 ounces each year. Several other Australian gold deposits were being examined and developed. The Ingliston gold mine at Meekathara, Western Australia, was reopened in 1978 after an inactive interval of 60 years. Whim Creek Consolidated Mining Co. was prepared, at the end of 1979, to proceed with heap-leaching of low-grade ore at the Haveluck deposit near Meekathara. North Kalgoorlie Mines, Ltd., in 1979, reconverted its Croesus ore treatment plant to handle gold ores. The Tasmania, Morning Star, and Berringa mines were to be reopened. A tin-gold prospect near Jingellic, New South Wales, was being explored in 1979, while at Roxby Downs, in South Australia, drilling confirmed the existence of a very large copper-uranium-gold deposit.

Brazil.—The figures for Brazilian gold production in 1976-77, shown in table 19, have been revised upward to bring them in line with the Brazilian Government's figure for 1978, which gives considerably more weight than in earlier years to estimated production by individual alluvial miners, or garimpeiros. Garimpeiros, who have been estimated to number 25,000 to 30,000, have been credited with 57% of 1978 gold production. Among the dozens of alluvial deposits being worked, the greatest activity was concentrated along the Tapajos and nearby rivers in the upper Amazon basin in Para Province, but there was also much activity in Roraima, Amapa, Maranhao, Bahia, Minas Gerais, and Mato Grosso Provinces. Virtually all of the lode mine gold, 131,000 ounces in 1978, came from the Morro Velho mine in Minas Gerais, which increased production 10% in 1978.

Docegas, the exploration subsidiary of Companhia Vale do Rio Doce, continued exploration of gold mineralization near Xinguara in southern Para. The Anglo American and Antunes Groups explored a deposit near Jacobina, Bahia, and announced the development of a mine to be ready for production in 1982.

Canada.—In 1978 (1979), 22 (21) mines produced gold. Of the Provinces, Ontario was the largest producer, yielding 42% (39%) of the national total, followed by Quebec with 27% (28%), British Columbia, with 12% (16%), and the Northwest Territory with 12% (11%). Gold from the Atlantic Provinces, and most of that from British Columbia and the Prairie Provinces was a byproduct of base metal mining. Byproduct gold made up about one-third of total gold produced. Details of the operation of individual mines were published in the Canadian Minerals Yearbook.

Colombia.—More than half of reported Colombian gold production came from placer deposits in northern Colombia, largely from the Nechi River and other streams in Antioquia Department. Much of the placer production was reported by companies operating sizable dredges, but a substantial amount of gold was recovered by individual miners using hand methods.

Dominican Republic.—The output of the Pueblo Viejo mine, the sole gold producer, was 336,073 ounces in 1978. Recovery grade averaged 0.11 ounce gold per ton. Mill capacity was increased 16% during 1978 to 9,300 tons per day, by installation of a new crushing plant and another ball mill circuit, and other major modifications to the mill. Exploration and metallurgical research continued on the sulfide ores underlying the oxide ore body. In October 1979, the Dominican Government bought the remaining 54% interest in the mine that was held in equal shares by two U.S. companies, Rosario Resources Corp. and Simplot Industries, Inc.

Ghana.—Gold production declined in 1978 for the second year, and then stabilized at about the same level in 1979. Ashanti Goldfields Corp., Ghana's main producer, announced plans to sink a new shaft to increase output of ore by 75,000 tons per year. The shaft was expected to be completed in about 4 years.

Papua New Guinea.—After increasing slightly in 1978, production fell 7% in 1979 as the grade of mined ore dropped. Virtually all of the gold was a byproduct of copper mined by Bougainville Copper Ltd. The international consortium exploring the Ok Tedi copper deposit estimated that the gold-enriched cap covering the primary ore body contains about 3.5 million ounces of gold. It was planned to mine the gold cap first, starting in 1984, over a 3 to 4 year period. Gold was being explored for in at least 10 other locations in Papua New Guinea.

Philippines.—Gold production increased in 1978, but then dropped back again in 1979. Three-fourths of the gold was a byproduct of copper mining, and revenues from gold became very important to the economics of several copper mines. High gold prices during 1978-79 stimulated plans for development of several gold deposits. Benguet Consolidated Inc., developed its large Dizon copper-gold deposit in Zambales Province and started production in January 1980. At the design production rate of 100,000 ounces of gold per year, about 12 years' reserves had been located. Benguet also undertook the expansion and operation of Atok - Big Wedge Mining Co's. mine at Itogon; ore production was to be increased from 100 tons per day to 600 tons per day by late 1980. Atlas Consolidated Mining & Development Corp. reopened its Masbate mine in 1979. It was expected to attain a production level of 90,000 ounces of gold per year. Manila Mining Corp.'s placer gold property near Surigao on northern Mindanao was expected to be in production by the end of 1979. Metals Exploration Asia Inc., was arranging financing for its Longos gold project in Camarines Norte, aiming for production in 1980.

The Philippines Central Bank's new gold refinery at Quezon City became fully operational in 1978, at a capacity of 600,000 ounces per year, and all Philippines gold producers were required to sell their gold to it.

South Africa, Republic of.—Production stabilized in 1978-79 at 22.6 million ounces per year, or 58% of world gold mine production. The 35 mines and two metallurgical recovery operations that were members of the Chamber of Mines accounted for essentially all of South African production. Data published by the chamber show that member mines in 1978 (1979) milled 86.1 (92.0) million short tons of ore, averaging 0.31 (0.29) ounce of gold per ton. Working costs averaged (in U.S. dollars) $102.92 ($127.14) per ounce, and ranged from $46.72 ($56.26) at East Driefontein to $233.00 ($308.41) at Free State Saaiplaas (Loraine). Production by the seven major mining groups was as follows, in million ounces: Anglo American Corp. of South Africa, Ltd., 8.4 (8.6); Gold Fields of South Africa, Ltd., 5.3 (5.2); Rand Mines, Ltd., 2.2 (2.2); Union Corp. 2.0 (1.9); General Mining & Finance Corp., 1.6 (1.5);

Anglo Transvaal Consolidated Investment Co. Ltd., 1.2 (1.2); and Johanesburg Consolidated Investment Corp., Ltd., 1.4 (1.5). The largest producing mines were, in million ounces, Vaal Reefs, 2.17 (2.16), West Driefontein 1.84 (1.68); East Driefontein 1.57 (1.56), Western Deep Levels 1.47 (1.54), and Free State Geduld 1.37 (1.21). Nine mines, and two metallurgical recovery operations, also produced uranium in 1978. South African demonstrated gold reserves at the end of the third quarter in 1979 were 530 million ounces, of which 78 million ounces were proven reserves grading 0.39 ounce per ton.

Several mines were expanding production or being readied for operation. At Gold Fields' Deelkraal mine, located south of Carletonville, on the Far West Rand, all major surface installations were essentially complete by yearend 1978. Initial stoping and trial milling were conducted in 1979. Development of the Elandsrand mine was 31 months ahead of schedule when production began in December 1978. Ore production in 1979 averaged nearly 50,000 tons per month, and was expected to reach 150,000 tons per month by early 1981, and ultimately 225,000 tons per month. At the Unisel mine, in the Orange Free State, underground development began in mid-1978 and production commenced in March 1979. Ore production was expected to build to a rate of 75,000 tons per month by the end of 1979.

U.S.S.R.—Gold production was estimated to have risen about 3% over the 2-year period. The export of gold by central economy countries to market economy countries was estimated[5] to amount to 13.2 million ounces in 1978 and 7.4 million ounces in 1979. Virtually all of that gold came from the U.S.S.R. Direct exports of gold by the U.S.S.R. to the United States made up 30% of U.S. gold imports in 1978, and 36% in 1979.

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[1] Physical scientist, Section of Nonferrous Metals.
[2] Ounce means troy ounce.
[3] Federal Register. V. 43, No. 137, July 17, 1978, p. 30538.
[4] Gold 1979. Published by Consolidated Gold Fields, Ltd.
[5] Gold 1980. Published by Consolidated Gold Fields, Ltd.

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Graphite

By Harold A. Taylor, Jr.[1]

Natural crystalline flake graphite was in short supply in 1978-79. Prices of imported flake graphite increased significantly in both years. Supplies of Mexican amorphous graphite remained sufficient, and substitution of it for scarcer crystalline flake appears to have been moderately successful. Domestic production of natural graphite increased in 1978 in both quantity and value from the 1977 level, and then decreased in 1979 from that of 1978, but quantitative data are not released for publication. Production will be impacted by the closing in late 1979 of the only domestic mine.

Production of manufactured graphite in 1978 increased 13% in quantity over that of 1977, and production in 1979 increased 9% over that of 1978.

Imports of natural crystalline and amorphous graphite in 1978 were up 15% in quantity over the 1977 level, but decreased 8% in 1979 from the 1978 level.

Table 1.—Salient natural graphite statistics

	1975	1976	1977	1978	1979
United States:					
Apparent consumption[1] short tons	[2]55,077	[2]66,862	[2]73,773	90,396	77,562
Exports do	10,586	12,236	13,783	9,595	8,623
Value thousands	$1,890	$2,388	$2,662	$2,304	$3,741
Imports for consumption[3] short tons	65,663	79,098	87,556	99,991	86,185
Value thousands	$5,698	$6,753	$8,058	$11,700	$13,035
World: Production short tons	497,500	[r]507,216	[r]557,544	589,270	576,680

[r] Revised.
[1] Excludes domestic production.
[2] Revised to include some manufactured graphite imported for consumption.
[3] Includes some manufactured graphite; see table 6.

Legislation and Government Programs.—National stockpile goals for strategic graphite, proposed in 1976 and reaffirmed in 1977 by the Federal Preparedness Agency of the General Services Administration, remained unchanged in 1978-79. Stockpile goals and inventories for each type of graphite are shown in table 2. There were no acquisitions or disposals of strategic graphite in 1978 or 1979.

The 3-year trial suspension on the import duty for natural crystalline graphite was extended until the end of June 1981.

Table 2.—Government yearend stocks of natural graphite

(Short tons)

Type of graphite	Goal	National stockpile inventory (December 31)	
		1978	1979
Madagascar crystalline flake	20,472	17,905	17,903
Sri Lanka amorphous lump	6,271	5,442	5,442
Crystalline, other than Madagascar and Sri Lanka	34,748	1,932	1,932
Non-stockpile-grade, all types	--	932	934

Source: General Services Administration. Stockpile Reports to the Congress, October 1978-March 1979 and October 1979-March 1980.

DOMESTIC PRODUCTION

The Southwestern Graphite Co., a division of Joseph Dixon Crucible Co., continued to be the only producing domestic graphite mine. Shipments from the mine, located near Burnet, Tex., were higher in 1978 than in 1977 but then dropped in 1979 from the 1978 level. It continues to account for only a very small portion of domestic supply. This mine was closed in November 1979 although shipments continued from stocks. Other graphite deposits in Alabama, Montana, and the Province of Saskatchewan, Canada, continued to receive the attention of investigators contemplating the development or redevelopment of additional mines. However, no mine openings seem likely in the near future.

Although crystalline flake graphite was in short supply throughout both years, plans for the development of a flake graphite deposit in the Alabama flake graphite district by International Carbon and Minerals Corp. did not proceed, owing to the large capital required to reopen and equip the mine.[3]

Reported production of manufactured graphite increased 13% to 359,388 tons in 1978 and increased 9% more to 391,401 tons in 1979. Electrode production increased 16% in 1978, and then 12% more in 1979. Production of high-modulus fibers grew rapidly, rising 140% in quantity in 1978 from that of 1977, and then 14% more in 1979 from that of 1978. The value per pound of high-modulus fiber decreased about 4% to about $40 in 1978. The value per pound then decreased 14% more to $35 in 1979, putting the price for composite materials in the neighborhood of $20 per pound.

Table 3.—Production of manufactured graphite in the United States, by use

Use	1978		1979	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Synthetic graphite products:				
Anodes	12,500	$19,592	14,973	$21,338
Cloth and fibers (low-modulus)	103	5,898	133	7,549
Crucibles, vessels, refractories	W	W	W	W
Electric motor brushes and machined shapes	W	W	W	W
Electrodes	256,045	396,550	285,950	430,361
High-modulus fibers	127	10,260	145	10,066
Unmachined graphite shapes	9,687	14,817	8,341	11,385
Other	50,210	98,067	44,946	82,443
Total	328,672	545,184	354,488	563,142
Synthetic graphite powder and scrap	30,716	33,297	36,913	20,724
Grand total	359,388	578,481	391,401	583,866

W Withheld to avoid disclosing company proprietary data; included with "Other."

Manufactured graphite was produced at 28 plants in 1978-79, with some additional production for inhouse use likely. Airco, Inc., was planning to construct a major new graphite electrode plant at Tallula, La., that will cost $150 million and is scheduled for completion in 1982.[3] Union Carbide Corp. was doing design engineering work on a proposed carbon fiber plant to be built at Greenville, S.C. The facility is expected to begin operation in 1981 with a planned initial production capacity of 400 tons per year of carbon fibers.[4] Avco Corp. was constructing a graphite fiber plant at Lowell, Mass., that will probably come onstream sometime in 1980.[5] Hercules has announced plans to more than double the capacity of its Salt Lake City, Utah, carbon fiber plant, for a total capacity of 230 tons, by early 1980.[6] The following is a list of principal producers of manufactured graphite:

Company	Plant location	Product[1]
Airco, Inc., Speer Div	Niagara Falls, N.Y	Anodes, electrodes, crucibles, motor brushes, refractories, unmachined shapes, powder.
Do	Punxsutawney, Pa.	
Do	St. Marys, Pa.	
Avco Corp., Specialty Materials Div	Lowell, Mass	High-modulus fibers.
The Carborundum Co., Graphite Products Div	Hickman, Ky	Electrodes, motor brushes, unmachined shapes, cloth.
Do	Niagara Falls, N.Y.	
Do	Sanborn, N.Y.	
Celanese Corp., Celanese Research Lab	Summit, N.J	High-modulus fibers.
Fiber Materials, Inc	Biddeford, Maine	Do.
B. F. Goodrich Engineered Systems Div., Super Temp Operation.	Santa Fe Springs, Calif	Other.
Great Lakes Carbon Corp	Morganton, N.C	Anodes, electrodes, powder.
Do	Niagara Falls, N.Y.	
Do	Rosamond, Calif.	
Hercules, Inc	Salt Lake City, Utah	High-modulus fibers.
HITCO (Subsidiary of Armco Steel Corp.)	Gardena, Calif	Cloth and high-modulus fibers.
ICI Americas, Inc	West Chester Pa	Other.
Pfizer, Inc., Minerals, Pigments & Metals Div	Easton, Pa	Do.
Poco Graphite, Inc	Decatur, Tex	Unspecified.
Polycarbon, Inc	North Hollywood, Calif	Cloth.
Stackpole Carbon Co	Lowell, Mass	High-modulus fibers, anodes, motor brushes, unmachined shapes, powder.
Do	St. Marys, Pa.	
Superior Graphite Co	Chicago, Ill	Powder and other.
Do	Hopkinsville, Ky.	
Union Carbide Corp	Clarksburg, W. Va	Anodes, electrodes, unmachined shapes, powder.
Do	Columbia, Tenn.	
Do	Niagara Falls, N.Y.	
Do	Yabucoa, P.R.	
United Catalysts, Inc	Louisville, Ky	Other.

[1] Cloth includes low-modulus fibers; electric motor brushes includes machined shapes; crucibles includes vessels.

CONSUMPTION AND USES

Reported consumption of natural graphite in 1978 (table 4) decreased 4% to 54,908 tons, and in 1979 increased 11% to 60,736 tons. The three major uses of natural graphite, refractories, foundries, and steelmaking, accounted for 59% of reported consumption in 1978 and 66% in 1979.

The actual amount of natural graphite consumed was greater than that shown in table 4, which reports only the results of a canvass of major known consumers. While this canvass probably gives a good indication of consumption patterns, caution is advised in using these data for absolute amounts owing to incomplete coverage and inconsistencies in company reporting. Apparent graphite consumption in 1978 was 90,396 tons, and was 77,562 tons in 1979, excluding domestic production.

Use of graphite fiber-metal matrix composites will increase as their costs drop to a small fraction of their present level.[7]

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Table 4.—Consumption[1] of natural graphite in the United States, by use

Use	Crystalline		Amorphous[2]		Total	
	Quantity (short tons)	Value	Quantity (short tons)	Value	Quantity (short tons)	Value
1978						
Batteries	W	W	W	W	1,596	$1,790,974
Brake linings	1,036	$1,335,223	2,541	$1,308,007	3,578	2,643,230
Carbon products[3]	624	565,268	885	725,642	1,509	1,290,910
Crucibles, retorts, stoppers, sleeves, nozzles	W	W	W	W	2,568	1,285,566
Foundries	937	335,471	9,532	1,424,144	10,468	1,759,615
Lubricants[4]	603	586,228	3,445	1,276,909	4,048	1,863,137
Pencils	1,302	979,797	410	163,331	1,713	1,143,128
Powdered metals	804	671,569	262	272,194	1,066	943,763
Refractories	1,064	202,496	12,415	2,037,717	13,478	2,240,213
Rubber	131	104,860	222	67,440	354	172,300
Steelmaking	340	148,765	8,293	1,262,180	8,633	1,410,945
Other[5]	8,929	4,465,651	1,133	489,626	5,897	1,878,737
Total	15,770	9,395,328	39,138	9,027,190	54,908	18,422,518
1979						
Batteries	W	W	W	W	W	W
Brake linings	1,019	1,555,501	1,524	908,405	2,543	2,463,906
Carbon products[3]	287	361,767	591	438,294	878	800,061
Crucibles, retorts, stoppers, sleeves, nozzles	W	W	W	W	W	W
Foundries	3,352	1,464,368	7,041	1,904,805	10,393	3,369,173
Lubricants[4]	768	867,686	2,281	1,354,413	3,049	2,222,099
Pencils	1,484	1,407,522	579	274,786	2,063	1,682,308
Powdered metals	425	456,635	415	356,145	840	812,780
Refractories	912	180,909	13,460	3,592,064	14,372	3,772,973
Rubber	104	86,499	245	79,292	349	165,791
Steelmaking	615	267,972	14,872	4,770,004	15,487	5,037,976
Other[5]	8,809	5,512,373	1,953	1,654,633	10,762	7,167,006
Total	17,775	12,161,232	42,961	15,332,841	60,736	27,494,073

W Withheld to avoid disclosing company proprietary data; included with "Other."

[1] Consumption data incomplete. Small consumers excluded.

[2] Includes mixtures of natural and manufactured graphite.

[3] Includes bearings and carbon brushes.

[4] Includes ammunition, packings, and seed coating.

[5] Includes paints and polishes, antiknock and other compounds, drilling mud, electrical and electronic products, insulation, magnetic tape, small packages, and miscellaneous and proprietary uses.

PRICES

Actual graphite prices are often negotiated between the buyer and seller, so price quotations represent the average of a range of prices. The source of information for imported graphite is the average customs value per ton of the different classes of imports, which can be derived from table 6. However, it should be noted that these mainly represent shipments of unprocessed graphite.

Average prices of graphite imports increased in 1978 and 1979. Prices for crystalline flake rose from $271 per short ton in 1977 to $327 per short ton in 1978 and $391 per short ton in 1979, or by 44% from 1977 to 1979. Prices for other natural crude (mostly amorphous) graphite rose from $66 per short ton in 1977 to $82 per short ton in 1978, and $100 per short ton in 1979, or by 52% from 1977 to 1979. These prices reflect the tightness of the market, decline in value of the dollar, increases in producers' costs generated by worldwide economic conditions, and/or the strong position of some graphite producers.

Representative yearend prices of several types of imported graphite, as published in the Engineering and Mining Journal, are shown in the following tabulation.[4] All prices are f.o.b. the foreign port or border station and have been converted from metric tons.

	Per short ton	
	1978	1979
Flake and crystalline graphite, bags:		
China, mainland	$227- $907	$181- $907
Germany, Federal Republic of	290-1,361	327-1,633
Madagascar	136- 431	181- 508
Norway	181- 322	236- 363
Sri Lanka	195- 603	227- 816
Amorphous, nonflake, cryptocrystalline graphite (80% to 85% carbon):		
Korea, Republic of (bags)	41- 50	59- 68
Mexico (bulk)	32- 50	36- 64

FOREIGN TRADE

The broad upward trend in exports of natural graphite was broken in 1978 and 1979, principally owing to the virtual cessation of exports to the Federal Republic of Germany.

Imports of natural graphite increased 15% to 96,684 tons in 1978, exceeding the previous high of 84,369 tons in 1977, and then dropped 14% to 82,768 tons in 1979. The U.S.S.R. became an important source of graphite in this time period; imports from the U.S.S.R. increased from 2,629 tons in 1977 to 3,659 tons in 1978 and 3,644 tons in 1979.

Table 5.—U.S. exports of natural graphite,[1] by country

Destination	1978		1979	
	Quantity (short tons)	Value	Quantity (short tons)	Value
Argentina	131	$35,881	76	$27,875
Australia	396	97,926	246	155,094
Belgium-Luxembourg	48	10,500	581	453,184
Brazil	130	40,936	22	7,411
Canada	3,636	863,591	2,556	1,202,201
Chile	156	32,433	3	2,107
Colombia	21	10,407	14	9,708
Denmark	25	3,738	35	10,420
France	56	24,052	93	40,772
Germany, Federal Republic of	12	12,310	80	37,685
Hong Kong	2	1,251	21	6,300
Hungary	--	--	10	16,650
India	42	10,608	12	7,950
Iran	33	16,806	--	--
Ireland	12	5,430	3	3,894
Israel	29	3,283	6	5,777
Italy	233	28,626	50	23,567
Japan	490	162,254	139	103,726
Korea, Republic of	27	10,509	77	28,989
Malaysia	2	524	10	1,394
Mexico	434	144,936	268	164,242
Netherlands	48	5,438	403	173,700
New Zealand	--	--	2	1,258
Peru	5	3,636	26	19,446
Philippines	3	3,819	--	--
Poland	2,179	325,663	2,683	429,524
Singapore	78	27,786	--	--
South Africa, Republic of	20	2,359	--	--
Spain	49	7,423	--	--
Sweden	--	--	49	13,973
Switzerland	3	1,260	6	2,439
Taiwan	108	56,477	42	20,386
Thailand	--	--	15	2,528
U.S.S.R.	--	--	185	303,867
United Kingdom	589	136,856	279	109,156
Uruguay	149	16,944	--	--
Venezuela	270	118,895	603	337,658
Other	179	81,097	28	17,854
Total	9,595	2,303,654	8,623	3,740,735

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[1] Amorphous, crystalline flake, lump or chip, and natural, not elsewhere classified.

Table 6.—U.S. imports for consumption of natural and artificial graphite, by country

Year and country	Natural						Artificial[1]		Total	
	Crystalline flake		Crystalline lump, chip or dust		Other natural crude and refined					
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1977	6,681	$1,810	309	$129	77,379	$5,124	3,187	$995	87,556	$8,058
1978:										
Austria	--	--	--	--	11	5	--	--	11	5
Belgium-Luxembourg	734	257	--	--	20	4	--	--	754	261
Brazil	260	73	--	--	229	62	--	--	489	135
Canada	--	--	--	--	122	36	717	144	839	180
China, mainland	276	115	--	--	2,770	781	--	--	3,046	896
France	531	156	--	--	79	26	(2)	1	610	183
German Democratic Republic	--	--	--	--	5	7	--	--	5	7
Germany, Federal Republic of	221	188	--	--	1,391	778	452	41	2,064	1,007
India	--	--	--	--	94	79	22	25	116	104
Italy	(2)	(2)	--	--	20	3	--	--	20	3
Japan	9	31	--	--	218	92	1,178	495	1,405	618
Korea, Republic of	--	--	--	--	26,082	1,475	--	--	26,082	1,475
Madagascar	4,191	1,255	--	--	674	235	--	--	4,865	1,490
Malaysia	337	98	--	--	--	--	(2)	1	337	99
Mexico	--	--	(2)	(2)	49,954	1,723	--	--	49,954	1,723
Mozambique	234	74	--	--	--	--	--	--	234	74
Netherlands	--	--	--	--	38	5	--	--	38	5
Norway	768	224	--	--	888	270	--	--	1,656	494
South Africa, Republic of	--	--	--	--	321	71	--	--	321	71
Sri Lanka	148	52	279	105	1,875	874	--	--	2,302	1,031
Sweden	--	--	--	--	23	36	--	--	23	36
Switzerland	--	--	--	--	1	2	916	987	917	989
U.S.S.R	--	--	--	--	3,659	708	--	--	3,659	708
United Kingdom	158	49	--	--	64	28	22	29	244	106
Total	7,867	2,572	279	105	88,538	7,300	3,307	1,723	99,991	11,700
1979:										
Australia	--	--	--	--	17	6	(2)	2	17	8
Austria	--	--	--	--	17	3	--	--	17	3
Brazil	1,458	505	112	39	1,250	394	--	--	2,820	938
Canada	--	--	--	--	27	7	751	189	778	196
China:										
Mainland	188	79	--	--	2,695	769	--	--	2,888	848
Taiwan	--	--	--	--	15	13	--	--	15	13
Finland	--	--	--	--	6	9	--	--	6	9
France	--	--	--	--	61	13	--	--	61	13
Germany, Federal Republic of	178	119	--	--	930	680	914	327	2,022	1,126
India	60	20	--	--	--	--	76	17	136	37
Japan	1	1	--	--	239	250	63	321	303	572
Korea, Republic of	--	--	--	--	11,574	788	--	--	11,574	788
Madagascar	3,379	1,351	--	--	1,782	573	--	--	5,161	1,924
Malaysia	--	--	--	--	218	75	--	--	218	75
Mexico	--	--	--	--	51,026	1,957	--	--	51,026	1,957
Netherlands	--	--	--	--	(2)	1	20	25	20	26
Norway	521	172	--	--	1,180	381	--	--	1,701	553
Sri Lanka	131	70	323	113	1,644	958	--	--	2,098	1,141
Sweden	--	--	--	--	33	61	--	--	33	61
Switzerland	--	--	--	--	2	4	1,594	2,011	1,596	2,015
U.S.S.R	--	--	--	--	3,644	710	--	--	3,644	710
United Kingdom	54	17	--	--	2	6	--	--	56	23
Total[3]	5,970	2,334	435	151	76,363	7,657	3,419	2,893	86,185	13,035

[1] Includes only that received in raw material form; excludes products made of graphite.
[2] Less than 1/2 unit.
[3] Data may not add to totals shown because of independent rounding.

WORLD REVIEW

World production of natural graphite increased 5.7% from 1977 to 1978, and decreased an estimated 2.1% from 1978 to 1979. Production of amorphous graphite in Mexico and the Republic of Korea continued to be adequate. Supplies of crystalline graphite became tight again.

Canada.—The Deep Bay graphite deposit near Reindeer Lake, Saskatchewan, continued to be assessed for development feasibility.[9] It is unlikely to be developed until some consumers sign long-term (3-year) contracts, thus assuring a market for the product. Deep Bay Graphite Co., Ltd., a subsidiary of Superior Graphite Co., owns a 60% interest, with Saskatchewan Mining Corp. holding the remaining 40%. Open pit reserves are estimated to be 1.8 million tons containing 10.32% carbon.

China, mainland.—A Japanese graphite-buying mission visited China from June 20 to June 27, 1979, and signed spot contracts for about 1,100 short tons of crystalline graphite at $476 per ton, with delivery scheduled for the last half of 1979. The mission inspected a 17,000- to 22,000-ton-capacity graphite refractory plant and associated mine in Shantung Province, and learned of plans to increase the capacity of this plant 20% to 40% by the end of 1979 and to develop large new graphite mines in Inner Mongolia and Heilungkiang Provinces. This spot purchase was necessary because a mine accident in the U.S.S.R. reduced imports from that country. Future purchases are more likely to be under long-term contract rather than spot purchase, since both the Japanese and Chinese prefer this method of operation.[10]

India.—A Government of India survey delineated indicated and inferred graphite reserves of 3.6 million short tons averaging 2.5% to 30% fixed carbon in Gujarat, 2.1 million short tons averaging 15% to 65% fixed carbon in Kerala, 1.8 million short tons averaging 15% to 65% fixed carbon in Bihar, and 1.1 million short tons in States other than these three and Orissa. Resources totaled 185 million short tons of low-grade material, almost all in Arunachal Pradesh and Kashmir. Reserves of the principal producing State, Orissa, are being evaluated.[11]

Madagascar.—Investigations into using mobile equipment to mine small lenses of graphite having high carbon content were made by several producing companies in order to improve current production rates.[12]

Mexico.—A conservative estimate of amorphous graphite reserves in Sonora, based principally on existing and assumed geological data on the coal deposits of the Barranca Formation in the area, were estimated to be 4 million tons, representing an 80-year supply at current mining rates.[13]

Pakistan.—Feasibility studies were made by the Pakistani Government on the high-quality crystalline graphite deposits in the Malakand area. These deposits were discovered in 1977 and have reserves reported to be 10 to 20 million tons.[14]

Table 7.—Graphite: World production, by country

(Short tons)

Country[1]	1976	1977	1978[p]	1979[e]
Argentina	[r]160	94	28	100
Austria	36,439	38,898	44,645	45,000
Brazil (marketable)	6,634	10,127	11,417	12,000
Burma[2]	177	106	309	280
China, mainland[e]	55,000	[r]66,000	88,000	110,000
Germany, Federal Republic of[3]	15,461	14,833	13,147	NA
India	[r]42,189	53,412	66,201	55,000
Italy	4,242	4,210	4,528	4,400
Korea, North[e]	[r]83,000	[r]83,000	83,000	83,000
Korea, Republic of	45,955	72,703	62,081	52,000
Madagascar	[r]19,193	17,336	18,326	18,700
Mexico	66,510	64,410	57,611	54,900
Norway	[r]9,999	10,028	11,153	12,000
Romania[e]	6,600	6,600	6,600	6,600
Sri Lanka	[r]10,073	9,783	11,581	12,000
South Africa, Republic of	584	1,004	643	700
U.S.S.R.[e]	105,000	105,000	110,000	110,000
United States	W	W	W	W
Total	[r]507,216	557,544	589,270	576,680

[e]Estimate. [p]Preliminary. [r]Revised. NA Not available. W Withheld to avoid disclosing company proprietary data.

[1]In addition to the countries listed, Czechoslovakia, Southern Rhodesia, and the Territory of South-West Africa (Namibia) are believed to have produced graphite during the period covered by this table, but output is unreported and available general information is inadequate for formulation of reliable estimates of output levels.

[2]Data are for fiscal year beginning April 1 of that stated.

[3]Data represent marketable production, including some produced from imported raw materials.

TECHNOLOGY

Technical developments continued to be concentrated on manufactured graphite and its uses in 1978. Some advances, however, did occur that pertained directly to either natural graphite or both natural and manufactured graphite.

A high-purity synthetic graphite has been developed to replace conventional graphite for increasing carbon contents of ductile iron heats.[15] A high-density, high-purity graphite packing material was introduced having outstanding chemical resistance and a broad temperature range that allows it to seal where conventional materials fail.[16] Development of a high-temperature bonded solid film lubricant containing graphite and molybdenum disulfide combined with a modified silicone resin was announced.[17] Solid graphite and carbon refractories are attacked during use by alkalis that act as catalysts for oxidation, resulting in volatilization, softening, or (usually) cracking of the object.[18]

Advanced composite materials, particularly graphite composites combining graphite with a resin such as epoxy, began to make major advances into new applications as the aircraft and automobile industries continued to search for lighter weight, high-strength substitutes for titanium, aluminum, and steel. About 2,300 pounds of graphite structual components will be used on the McDonnell-Douglas F-18 military airplane, a weight savings of 20% to 30%. The material will be used for both upper and lower wing covers, for the vertical and horizontal tails, fuselage panels, and access doors. Graphite and other composites were also being used in secondary structural work, such as trailing edges and doors in some commercial jetliners, but have not been used in such critical, highly loaded applications as wings or landing gears.[19]

Graphite composites, including body, chassis, and power train components, were being developed by the Ford Motor Co. in a prototype development program.[20] An air conditioner compressor bracket made of graphite composite will be used on all 1980 Fords with 2.3-liter engines. This part will weigh only 2 pounds compared with the 7-pound metallic part it is replacing.[21] Hercules, Inc., one of the largest manufacturers of graphite composites, developed a test car utilizing graphite fibers extensively.[22]

Other new uses for graphite fiber composites include high-temperature insulation slabs that can be worked to meet specific conditions[23] and graphite aluminum tubes offering bending and/or torsional properties comparable to metals but with weight reductions up to 80%.[24]

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[1]Physical scientist, Section of Nonmetallic Minerals.

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Gypsum

By J. W. Pressler[1]

The gypsum industry continued expanding in the biennial period of 1978-79, as reflected by over 1.5 million new housing (public and private) unit starts per year for the quadrennial period of 1976-79, with 1978 the record year, slightly over 2 million starts. In 1978, output of crude gypsum increased 11% to a record 14.9 million tons, but decreased 2% in 1979. Production of calcined gypsum increased 12% to 14 million tons in 1978, and continued with an increase of 4% in 1979 to set a new annual record of 14.6 million tons. Sales of gypsum products in 1978 increased 5% to 21.6 million tons, and increased 1% more in 1979 to 21.8 million tons. Imports of crude gypsum increased 17% in 1978 to a record 8.3 million tons, but decreased 6% in 1979. Total value of gypsum products sold in 1978 increased 25% to $1.1 billion, and followed with a 13% increase in 1979 to $1.3 billion.

Table 1.—Salient gypsum statistics

(Thousand short tons and thousand dollars)

	1975	1976	1977	1978	1979
United States:					
Active mines and plants[1]	110	117	115	116	113
Crude:					
Mined	9,751	11,980	13,390	14,891	14,630
Value	$44,654	$59,888	$74,341	$92,726	$99,868
Imports for consumption	5,448	6,231	7,074	8,308	7,773
Byproduct gypsum sales	369	573	797	669	828
Calcined:					
Produced	9,181	11,036	12,590	14,041	14,543
Value	$186,478	$236,775	$277,835	$387,010	$442,157
Products sold (value)	$525,051	$654,860	$910,526	$1,248,013	$1,391,993
Exports (value)	$10,481	$32,594	$15,703	$19,804	$22,388
Imports for consumption (value)	$19,817	$21,756	$31,398	$63,882	$65,079
World: Production	65,279	r73,610	r79,042	84,586	81,954

rRevised.

[1] Each mine, calcining plant, or combination mine and plant is counted as one establishment; includes plants that sold byproduct gypsum.

DOMESTIC PRODUCTION

The United States was the world's leading producer of gypsum, accounting for 18% of the total world output.

In 1979, 42 companies mined crude gypsum at 65 mines in 22 States. Output decreased 2% compared with the record year of 1978. Leading producing States were Michigan, Texas, Iowa, California, Oklahoma, and Nevada. These six States produced more than 1 million tons each and together accounted for 71% of the total domestic production. Stocks of crude ore at mines and plants at yearend 1979 were 3.9 million tons.

Leading companies in 1979 were United States Gypsum Co. (12 mines), National Gypsum Co. and Georgia-Pacific Corp. (6 mines each), Celotex Div. of Jim Walter Corp. (4 mines), The Flintkote Co. (3 mines), and Pacific Coast Building Products, Inc. (1 mine). These 6 companies, operating 32 mines, produced 82% of the total crude gypsum in 1979.

Leading individual mines in 1979 were United States Gypsum's Alabaster mine in Iosco County, Mich.; United States Gypsum's Plaster City mine in Imperial County, Calif.; National Gypsum's Tawas mine in Iosco County, Mich.; United States Gypsum's Sweetwater mine in Nolan County, Tex.; United States Gypsum's Sigurd mine in Sevier County Utah; United States Gypsum's Shoals mine in Martin County, Ind.; and Georgia-Pacific's Acme mine in Hardeman County, Tex. These seven mines accounted for 37% of the national total. Average output per mine in 1979 for the 65 U.S. mines was 225,000 tons, compared with 194,000 tons per mine in 1977.

In 1979, 13 companies calcined gypsum at 72 plants in 30 States. Output increased from 12.6 million tons of calcine valued at $278 million in 1977 to 14.5 million tons valued at $442 million in 1979, a tonnage increase of 16% and a value increase of 59% compared with that of 1977. Output in 1979 was a new annual record. Leading States were California, Texas, New York, and Iowa. These 4 States, with 23 plants, accounted for 38% of the national output.

Leading companies were United States Gypsum Co. (22 plants), National Gypsum Co. (19 plants), Georgia-Pacific Corp. (9 plants), The Flintkote Co. (6 plants), and Celotex Div. of Jim Walter Corp. (5 plants). These 5 companies, operating 61 plants, accounted for 84% of the national output in 1979.

Leading individual plants were United States Gypsum's Plaster City plant, Imperial County, Calif.; United States Gypsum's Stony Point plant, Rockland County, N.Y.; United States Gypsum's Detroit plant in Wayne County, Mich.; Weyerhaeuser's Briar plant, Howard County, Ark.; United States Gypsum's Shoals plant, Martin County, Ind.; Pacific Coast Building Product's plant in Clark County, Nev.; Georgia-Pacific's Acme plant, Hardeman County, Tex.; United States Gypsum's Southard plant, Blaine County, Okla.; United States Gypsum's Sweetwater plant, Nolan County, Tex.; and United States Gypsum's Fort Dodge plant, Webster County, Iowa. These 10 plants accounted for 30% of the national output. Average output per plant in 1979 for the 72 U.S. plants was 202,000 tons, compared with 177,000 tons per plant in 1977.

In 1979, the following companies sold a total of 828,000 tons of byproduct gypsum, valued at $5 million, for agricultural purposes: Occidental Petroleum Corp., Allied Chemical Corp., Valley Nitrogen Producers Inc., and Victor Material Co. (all in California), Occidental Petroleum Corp. (Florida), Texasgulf Inc. (North Carolina), and American Cyanamid Co. (Georgia).

Several gypsumboard plant expansions and two plant startups increased the national production capacity an additional 1.23 billion square feet per year. The available capacity of operating gypsumboard plants in the United States at yearend 1979 was 18.23 billion square feet per year, a 7% increase compared with that of yearend 1977. Total 1979 gypsumboard production in the United States was 16.7 billion square feet. This indicated a 92% national utilization of capacity for the year. In 1978-79, National Gypsum Co. began operations of two new gypsum wallboard plants, one in Rensselaer in Rensselaer County, N. Y., and the other in Wilmington, New Hanover County, N. C. The company also announced that the output of the Phoenix, Ariz., plant would be increased 40% by 1980. United States Gypsum Co. announced several plant expansions and modernizations during the biennium, including the Philadelphia, Pa., plant and the Sweetwater, Tex., plant. The Philadelphia plant is one of the oldest in the United States, and has produced more than 4 billion square feet of wallboard since 1929. In 1979, Domtar Gypsum America, Inc., completed the multimillion-dollar expansions of its two wallboard plants in Long Beach and Antioch, Calif., which represents a total 32% increase in capacity.[3]

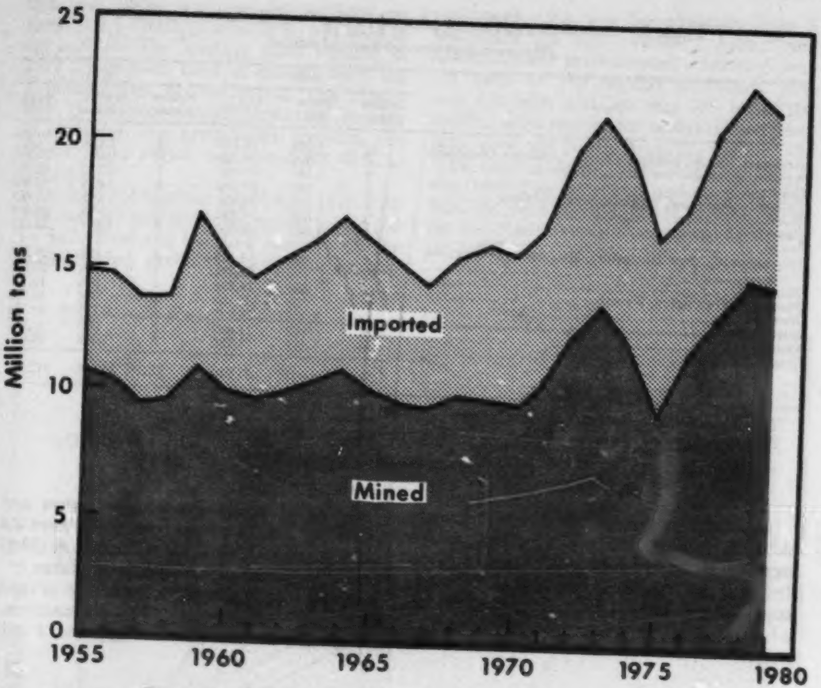

Figure 1.—Supply of crude gypsum in the United States.

Table 2.—Crude gypsum mined in the United States, by State

(Thousand short tons and thousand dollars)

State	1978			1979		
	Active mines	Quantity	Value	Active mines	Quantity	Value
Arkansas, Kansas, Louisiana	5	1,243	5,891	5	1,171	5,584
Arizona	4	184	955	4	231	1,245
California	4	1,578	9,017	3	1,624	10,355
Colorado	6	235	882	4	275	1,727
Idaho, Montana, South Dakota, Washington	8	159	1,182	6	161	1,393
Indiana, New York, Virginia	6	1,410	10,263	4	1,430	13,021
Iowa	7	1,602	12,175	6	1,695	13,777
Michigan	5	2,765	15,526	5	2,526	14,633
Nevada	6	1,335	7,883	3	1,075	6,771
New Mexico	3	263	2,649	3	251	3,244
Ohio	1	171	1,375	1	151	1,359
Oklahoma	6	1,398	8,097	6	999	5,668
Texas	7	1,864	11,060	7	1,903	11,438
Utah	6	316	2,777	5	772	6,552
Wyoming	3	370	2,995	3	366	3,100
Total[1]	77	14,891	92,726	65	14,630	99,868

[1] Data may not add to totals shown because of independent rounding.

Table 3.—Calcined gypsum produced in the United States, by State

(Thousand short tons and thousand dollars)

State	1978			1979		
	Active plants	Quantity	Value	Active plants	Quantity	Value
Arkansas, Illinois, Indiana, Kansas, Louisiana, Oklahoma	12	2,729	70,418	12	2,772	77,277
Arizona, Colorado, New Mexico, Utah	6	599	16,528	6	591	17,401
California	7	1,737	37,296	7	1,818	45,651
Delaware, Maryland, Virginia, North Carolina	5	967	37,966	6	1,074	41,569
Florida	3	626	15,738	3	659	18,359
Georgia	3	589	16,316	3	678	22,098
Iowa	5	1,064	28,039	5	1,077	32,121
Massachusetts, New Hampshire, New Jersey, Pennsylvania	5	742	16,435	5	822	23,063
Michigan	4	773	24,824	4	752	27,280
Montana, Washington, Wyoming	4	495	14,895	4	505	16,597
Nevada	3	739	20,163	3	802	15,010
New York	5	1,212	39,227	5	1,187	48,074
Ohio	3	426	11,429	3	408	11,667
Texas	6	1,341	37,739	6	1,398	46,010
Total	71	[1]14,041	387,010	72	14,543	442,157

[1] Data do not add to total shown because of independent rounding.

CONSUMPTION AND USES

Apparent consumption of crude gypsum in 1979 (production plus imports, minus exports) increased 9% to 22.3 million tons. Imports provided 35% of the crude gypsum consumed. Apparent consumption of calcined gypsum in 1979 increased 16% to 14.5 million tons.

Stocks of crude gypsum at mines and calcining plants at yearend 1979 were 3.9 million tons. Of this, 1.9 million tons (50%) was at calcining plants in coastal States.

Of the total gypsum products sold or used in 1979, 5.8 million tons (37%) was uncalcined. Of the total uncalcined gypsum, 4 mil-

Table 4.—Gypsum products (made from domestic, imported, and byproduct gypsum) sold or used in the United States, by use

(Thousand short tons and thousand dollars)

Use	1978		1979	
	Quantity	Value	Quantity	Value
Uncalcined:				
Portland cement	4,210	36,897	4,024	38,223
Agriculture[1]	1,508	11,315	1,700	14,064
Fillers and miscellaneous	163	4,298	124	3,846
Total	5,881	52,510	[2]5,849	56,133
Calcined:				
Industrial plaster	383	24,177	365	23,663
Building plaster:				
Regular base coat	221	10,580	134	6,733
Mill-mixed base coat	110	6,854	98	6,725
Veneer plaster	107	8,719	98	8,591
Gaging, molding, and Keene's cement	32	2,294	30	2,493
Other[3]	56	2,399	56	2,892
Total	526	30,846	416	27,434
Prefabricated products[4]	14,799	1,140,480	15,203	1,284,763
Total calcined	15,708	1,195,503	15,984	1,335,860
Grand total	21,589	1,248,013	21,833	1,391,993

[1] Includes 669,063 tons of byproduct gypsum in 1978 and 828,254 tons in 1979.
[2] Data do not add to total shown because of independent rounding.
[3] Includes roof deck concrete and other uses.
[4] Includes weight of paper, metal, or other materials.

lion tons (69%) was used for portland cement and 1.7 million tons (29%) was used in agriculture. The leading sales regions in 1979 for gypsum used in cement were the Atlantic, West South-Central, and Mountain; these three regions accounted for 44% of the total. For agricultural gypsum, the Pacific sales region accounted for 69% of the total.

Of the total calcined gypsum in 1979, 95% was used for prefabricated products and 5% for industrial and building plasters. Of the prefabricated products, 75% was regular wallboard, 19% was fire-resistant Type X wallboard, 3% was veneer base, and sheathing and predecorated wallboard were 1% each. Of the regular wallboard, 86% was 1/2 inch and 7% was 3/8 inch. The leading sales regions for prefabricated products were the South Atlantic, Pacific, and West South-Central, accounting for 49% of the total. For industrial and building plasters, the East North-Central, Middle Atlantic, and Pacific regions accounted for 56% of the total.

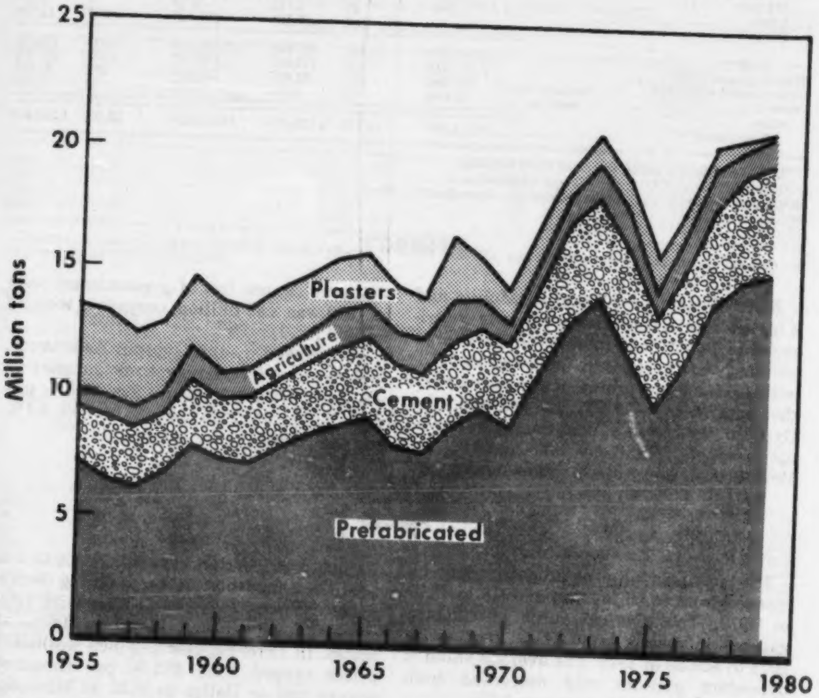

Figure 2.—Sales of gypsum products, by use.

Table 5.—Prefabricated products sold or used in the United States, by product

Product	1978 Thousand square feet	1978 Thousand short tons[1]	1978 Value (thousands)	1979 Thousand square feet	1979 Thousand short tons[1]	1979 Value (thousands)
Lath:						
3/8 inch	119,942	91	$9,246	117,729	92	$9,827
1/2 inch	6,504	6	460	7,330	7	665
Total	126,446	97	9,706	125,059	99	10,492
Veneer base	456,803	409	31,467	444,154	396	33,498
Sheathing	251,335	236	20,470	220,006	204	20,278
Regular gypsumboard:						
3/8 inch	739,512	572	46,864	732,575	596	54,728
1/2 inch	11,424,155	9,951	743,268	11,247,016	9,796	805,538
5/8 inch	721,053	668	57,685	833,493	777	74,332
1 inch	19,398	36	2,742	20,816	43	3,263
Other[2]	262,324	204	17,121	221,619	132	14,927
Total	13,166,442	11,431	867,680	13,055,519	11,344	952,788
Type X gypsumboard	2,191,844	2,403	175,683	2,617,147	2,923	226,689
Predecorated wallboard	234,386	207	31,617	252,883	224	37,641
Other	17,414	16	3,854	14,062	13	3,377
Grand total	16,444,670	14,799	[3]1,140,475	16,728,830	15,203	1,284,763

[1] Includes weight of paper, metal, or other material.
[2] Includes 1/4, 5/16, 7/16, and 3/4-inch gypsumboard.
[3] Data do not add to total shown because of independent rounding.

ENERGY

More efficient production scheduling and a higher rate of operational capacity contributed to a continued increase in the energy efficiency of the gypsum industry in 1979, with a 15.2% improvement compared with the base year of 1972. At yearend, the Gypsum Association announced improvement targets of 15% by 1980 and 22% by 1985. British thermal unit consumption per thousand square feet of gypsumboard sales in 1979 was 2.62 million, compared with 2.7 million in 1977.

As reported by the Gypsum Association, fuel sources for the gypsum industry at yearend 1979 were natural gas, 81.8%; propane, 7.7%; electricity, 5.5%; fuel oil, 4.1%; and coal, 0.9%.

PRICES

The average value of crude gypsum increased from $6.23 per ton in 1978 to $6.83 in 1979. The average value of calcined gypsum increased from $27.56 per ton in 1978 to $30.40 in 1979. The average value of byproduct gypsum sold decreased from $6.46 in 1978 to $6.05 per ton in 1979.

The average value of gypsum products sold or used increased from $57.81 in 1978 to $63.70 per ton in 1979. In 1979, prefabricated products were valued at $84.51 per ton, industrial plasters at $64.83 per ton, building plaster at $65.95 per ton, and uncalcined products at $9.60 per ton.

Quoted prices for gypsum products are published monthly in Engineering News-Record. Prices at yearend 1978 and 1979 showed a wide range, based on delivered prices. In 1978, regular 1/2-inch wallboard prices ranged from $81.00 per thousand square feet at Dallas to $135 at Minneapolis, and in 1979, ranged from $87.00 per thousand square feet in Dallas to $140.00 at Cleveland and Minneapolis. Prices for building plaster in 1978 ranged from $57.45 per ton at Los Angeles to $127.00 at New York, and in 1979, ranged from $75.00 at St. Louis to $133.00 at New York.

FOREIGN TRADE

In 1979, the gypsum industry continued to rely on imports for slightly more than one-third of apparent consumption. Imports of crude gypsum were from Canada (73%), Mexico (24%), and Spain, the Dominican Republic, Norway, Jamaica, Italy, Poland, and the United Kingdom, (the remaining 3%). Imports decreased 6% compared with the record year of 1978 to 7.8 million tons. Most of the imported crude gypsum was mined by subsidiaries of U.S. companies in Canada and Mexico. For 1978 and 1979, total value of gypsum and gypsum products imported was $64 million and $65 million, respectively, more than doubling the 1977 level of $31.4 million. Most of the increase was represented by the importation of 310 million square feet of wallboard from Canada (80%) and Mexico (20%) in 1978, and 344 million square feet in 1979 from Canada (96%) and Mexico (4%), a new alltime annual record. Total value of gypsum product exports to all countries was $19.8 million in 1978 and $22.4 million in 1979, substantial increases compared with that of 1977.

Table 6.—U.S. exports of gypsum and gypsum products

(Thousand short tons and thousand dollars)

Year	Crude, crushed, or calcined		Other manufactures n.e.c. (value)[1]	Total value
	Quantity	Value		
1976	284	6,739	25,855	32,594
1977	143	6,090	9,613	15,703
1978	132	8,752	11,052	19,804
1979	91	10,891	11,497	22,388

[1] Includes gypsum or plaster building boards and lath (TSUSA 245.7000), and articles, not specifically provided for, of plaster of Paris (TSUSA 512.4500).

Table 7.—U.S. imports for consumption of gypsum and gypsum products

(Thousand short tons and thousand dollars)

Year	Crude		Ground or calcined		Alabaster manufactures[1] (value)	Plasterboard[2] (value)	Other manufactures n.s.p.f.[3] (value)	Total value
	Quantity	Value	Quantity	Value				
1976	6,231	18,061	22	224	1,572	NA	1,899	21,756
1977	7,074	21,949	4	190	1,955	4,836	2,468	31,398
1978	8,308	33,085	3	306	2,976	24,710	2,805	63,882
1979	7,773	34,095	2	194	2,319	25,379	3,092	65,079

NA Not available.

[1] Includes imports of jet manufactures, which are believed to be negligible.

[2] Includes gypsum or plaster building boards and lath (TSUSA 245.7000).

[3] Comprised of "articles, not specifically provided for, of plaster of Paris, with or without reinforcement" (TSUSA 512.3100, 512.3500, 512.4100, and 512.4400).

Table 8.—U.S. imports for consumption of crude gypsum, by country

(Thousand short tons and thousand dollars)

Country	1978		1979	
	Quantity	Value	Quantity	Value
Canada[1]	6,160	25,995	5,700	24,324
Dominican Republic	144	1,292	80	686
France	29	126	--	--
Italy	(2)	27	(2)	28
Jamaica	167	343	5	34
Mexico	1,610	4,520	1,851	8,370
Norway	--	--	12	49
Poland	--	--	(2)	1
Spain	198	782	125	604
United Kingdom	(2)	(2)	(2)	(2)
Total	8,308	33,085	7,773	[3]34,095

[1] Includes anhydrite.

[2] Less than 1/2 unit.

[3] Data do not add to total shown because of independent rounding.

WORLD REVIEW

Domestic and foreign resources of gypsum are adequate for any foreseeable time. World reserves are conservatively estimated at 2.4 billion tons. Total world production figures may be somewhat low since in some countries only sales of gypsum are recorded, and much of the mine production is consumed by the mining company in what is frequently a very integrated industry.

Algeria.—A new gypsum plant came onstream at Fleurus, Algeria, in 1978. A Knauf conveyor kiln has a capacity of 450 tons per day of anhydrous plaster, and a uniflow rotary kiln has a capacity of 400 tons per day of plaster of Paris. In addition to these gypsum-based products, 600,000 square meters per year of partition panels for housing construction is produced on continuous-casting machines. The gypsum mine is adjacent to the plant; the fuel is natural gas.[3]

Argentina.—In 1978, Argentina called for international tenders for the construction of a gypsum-based sulfuric acid plant to be constructed at Marlargue in the Province of Mendoza. The plant will have a capacity of 165,000 tons per year of acid and an equal quantity of cement. The acid will be used for processing uranium ore.[4]

Australia.—There were two major plaster manufacturers in Australia in 1979—Australian Gypsum Industries Ltd. (AGI) and CSR Ltd. Both companies were active in South Australia, where combined operations account for 75% of the country's total output of 1 million tons per year. AGI's mining operations are at Lake MacDonnell, and the ore is railed and shipped to plaster mills and plasterboard works in Sydney, Melbourne, Brisbane, and Adelaide. CSR operated mainly at Kangaroo Island, off the south coast, and shipped to plants in Adelaide, Sydney, and Melbourne.[5]

Botswana.—The only commercial deposit of gypsum has been discovered by the Geological Survey and Mineral Research (Pty.) Ltd. near Bodianamane Pan, west of the Topsi siding. Gypsites containing selenite crystals in a brown, sandy soil were characterized.[6]

Canada.—Canada was the second leading producer of crude gypsum in 1979, accounting for 11% of the world total with shipments of 8.9 million tons, a slight increase over the 1978 level. In 1978, 68% of the gypsum was shipped from Nova Scotia, followed by Newfoundland (11%), Ontario (9%), and British Columbia (9%). Exports in 1979 to the United States by Canadian subsidiaries of U.S. companies were 5.7 million tons, 64% of total Canadian shipments for the year. Westroc Industries Ltd.'s Drumbo underground mine in Ontario (reported in the 1977 Minerals Yearbook chapter on gypsum under both Technology and World Review) came onstream in 1979 and is producing at its capacity of 250,000 tons per year, although production difficulties and water problems were experienced during the year. Other Canadian producers besides Nova Scotia and Newfoundland mainly supplied domestic demand. In Ontario, an expansion program at Caledonia by Domtar, Inc., was progressing on schedule in 1979. The project will include a complete new board plant, operative early in 1980, and a new mine development schedule for completion in 1985. Additional capacity at the Canadian Gypsum Co., Ltd.'s Hagerstown plant was onstream in 1979. A new quarry operation at Amaranth, Manitoba, was providing crude gypsum to Prairie board plants operated by Westroc.[7]

China, mainland.—The first known large highgrade deposit of gypsum was found in 1979 in Ningxia. The deposit is 50 to 100 meters thick and covers an area of 10 square kilometers, and is suitable for strip mining. The reserves are estimated at more than 1 billion tons.[8]

Egypt.—The Manganese Sinai Co. of Cairo instituted a project in 1978 to increase the production of gypsum at the Ras Malab deposit in the Sinai fivefold. Planned production by 1982 will be 260,000 tons per year.[9]

France.—Lafarge is Europe's principal producer of plaster and gypsum products, with six interrelated subsidiaries operating 3 gypsum quarries, 12 plaster plants, and 6 block factories. Gypsum wallboard is produced at three modern plants at Carpentras, Ottmarsheim, and Auneuil under the trade name "Pregypan-Rigips," a joint venture with National Gypsum Co. of the United States. Production capacity is 45 million square meters of board annually. Of the three Pregypan-Rigips plants, two use natural gypsum, but the third one uses phosphogypsum from the manufacture of phosphoric acid.[10]

Germany, Federal Republic of.—Published figures indicate output of about 2.5 million tons per year. However, actual mine production is in the 8-million-ton-per-year range, most of which is consumed captively by plaster and plasterboard manufacturers, and thus not recorded. Although the construction industry consumes the major portion, the Federal Republic of Germany is the world's largest producer of specialty gypsum cements for molding plaster as well as dental and medical plasters. The principal reserves are in Lower Saxony, Baden-Wurttemberg, the Upper Weser region, the Egge region, the Teutoburger Forest, and Franconia. Although a large amount of byproduct gypsum is available, only a small proportion is currently utilized.[11]

India.—India's gypsum reserves were re-estimated in 1978 at about 1.2 billion tons. High-grade deposits are located in Rajasthan, Jammu, and Kashmir, and lower grades are found in Tamil Nadu, Gujarat, and Himachan Pradesh. Natural, byproduct, and marine gypsum are included. Production of 900,000 tons in 1979 was mostly consumed in the cement, fertilizer, plaster of Paris, soil reclamation, and housing construction industries. Negotiations continued in 1979 for a plant in the Kashmir Valley for the recovery of sulfur from gypsum, the first of its kind in India.[12]

Iran.—The total production of gypsum, including some uncalcined used for cement and agricultural fertilizer, is estimated in 1979 to have been over 4 million tons per year. The greater part is used in the manufacture of plaster, and is made by the traditional method in field shaft kilns, involving a calcining period of several days. The new Mazanderan Gypsum Co.'s plant near Semnan, with a capacity of 1,000 tons per day, was placed onstream in 1979. Hemihydrate plaster and anhydrous plaster are produced in equal quantities for markets around the Persian Gulf. Other similar gypsum plaster manufacturing plants are under construction at Tabriz and Yazd. Two additional plants at Mashad (capacity 500 tons per day) and Ahwaz near the Persian Gulf (capacity 1,000 tons per day) use rotary kilns for calcining gypsum to produce mixed-phase wall plaster and hemihydrate plaster of Paris. The rotary kilns are fired with heavy fuel oil and were commissioned in mid-1978.[13]

Italy.—The production of gypsum has been about 4.5 million tons per year in the past few years. The source has been from a number of small quarries spread throughout the country, but especially concentrated in the Provinces of Ravenna, Pesaro Urbino, Bologna, and Reggio Emilia.[14]

Lebanon.—The production of gypsum remained almost static in 1978 and 1979 owing to turmoil and stagnation of the economy. A small industry produced only for domestic consumption.[15]

Somalia.—One of the largest known deposits of gypsum is located in Somalia. Although it is near-surface and located near a coastline, it is not considered an economic proposition because of the lack of local markets.[16]

South Africa, Republic of.—South Africa's somewhat limited gypsum industry exhibited two dull years in 1978-79, reflecting a listless domestic market and major declines in exports. Volume of sales were off 12% in 1978 and 4% in 1979. However, it is the only African country with a significant production of gypsum. The principal producer is Gypsum Industries Ltd., with a capacity of about 620,000 tons per year at three mines, followed by Anglo-Alpha Cement Ltd., which produces about 100,000 tons per year in the Northern Cape Province solely to supply its own needs for a cement retarder.[17]

Spain.—The Flakt Industrial Division of Sweden installed a gypsumboard production line at Española de Placa de Yeso S.A.'s plant, which came onstream in 1979.[18]

Thailand.—Large deposits of gypsum are found in Pichit, Surat Thani, and Nakhon Sawan, with many smaller deposits elsewhere. Reserves are very large. About 90% of the present production of 300,000 to 400,000 tons per year is sold to cement plants as a set-retarder. Malaysia is the only present market for exports.[19]

U.S.S.R.—A commercial gypsum deposit was discovered at Tikhoozersk. It has sufficient reserves to supply the requirements of the cement division of Noralisk Mining and Metallurgy Combine in the Soviet Union for several decades.[20]

Yugoslavia.—The Yugoslav Government reported the discovery of a high-quality gypsum deposit in 1979 near Kulen Vakuf in Bosnia-Hercegovina. Estimated at 30 million tons, the new mine will be part of the Komara enterprise, with exploitation to begin in 1980.[21]

Table 9.—Gypsum: World production, by country

(Thousand short tons)

Country[1]	1976	1977	1978[p]	1979[e]
North America:				
Canada[2 3]	6,616	7,974	8,901	[e]8,933
Cuba[e]	94	100	105	100
Dominican Republic	[r]243	249	190	100
El Salvador	[e]7	8	8	8
Guatemala	15	35	42	[e]28
Honduras	[e]11	20	[e]25	25
Jamaica	279	237	144	[e]64
Mexico	1,559	1,649	1,938	2,100
Nicaragua	[e]33	40	[e]40	40
United States[5]	11,980	13,390	14,891	[e]14,630
South America:				
Argentina	559	603	609	620
Bolivia	[e]1	--	--	--
Brazil	601	599	523	600
Chile	[r]134	225	246	[e]240
Colombia	226	231	281	300
Ecuador	48	48	50	50
Paraguay	18	15	10	10
Peru	189	237	263	240
Venezuela	[r]122	172	404	400
Europe:				
Austria[2]	849	722	766	840
Belgium[2]	242	185	202	210
Bulgaria	300	388	[e]400	400
Czechoslovakia	728	752	770	770
France[2]	7,308	6,649	6,654	6,500
German Democratic Republic	332	335	341	330
Germany, Federal Republic of (marketable)[2]	2,315	2,445	2,467	2,500
Greece	490	452	474	500
Ireland	391	377	432	450
Italy	[r e]4,600	4,608	[e]4,600	4,600
Luxembourg	2	3	1	1
Poland[e]	[e]1,380	1,477	1,488	1,500
Portugal	176	194	[e]198	190
Spain	[r e]4,600	6,043	6,063	5,000
Switzerland[e]	80	80	80	80
U.S.S.R.[e 4]	5,500	5,700	5,800	6,000
United Kingdom[2]	3,693	3,648	3,662	3,600
Yugoslavia	[r]505	704	660	500
Africa:				
Algeria[e]	190	190	190	210
Angola[e]	[r]22	[r]27	27	27
Egypt	514	561	880	900
Ethiopia	--	7	1	1
Kenya[2]	86	29	33	33
Libya	66	320	200	200
Mauritania	12	11	15	15
Niger	3	[e]3	3	3
South Africa, Republic of	532	485	429	[e]416
Sudan[2]	20	17	22	22
Tanzania	11	9	24	24
Tunisia	43	[e]44	[e]44	44
Zambia	[r]5	5	2	2
Asia:				
Afghanistan	NA	NA	7	NA
Burma	50	37	42	40
China:				
Mainland[e]	1,100	1,100	1,100	1,100
Taiwan[e]	3	8	4	[e]3
Cyprus	[r]71	92	76	[e]72
India	801	858	941	950
Iran	7,165	7,600	8,800	7,000
Iraq[e]	180	180	180	180
Israel	220	[e]220	[e]220	220
Japan[e 4]	[r]3,711	[r]3,950	4,580	4,740
Jordan	23	24	40	[e]66
Korea, Republic of[e 4]	550	660	680	680
Lebanon	[e]14	17	13	12
Mongolia[e]	[r]28	30	30	30
Pakistan	493	312	279	330
Philippines[5]	3	2	--	--
Saudi Arabia[e]	19	22	231	[e]330
Syrian Arab Republic	69	94	95	70
Thailand	[r]295	419	309	[e]388
Turkey	36	72	67	70

See footnotes at end of table.

Table 9.—Gypsum: World production, by country —Continued

(Thousand short tons)

Country[1]	1976	1977	1978[p]	1979[e]
Asia: —Continued				
Vietnam[e]	11	13	15	15
Oceania: Australia	[r]1,038	1,010	1,279	1,300
Total	[r]73,610	79,042	84,586	81,954

[e] Estimate. [p] Preliminary. [r] Revised. NA Not available.

[1] Gypsum is also produced by Romania, but production data are not available.

[2] Includes anhydrite.

[3] Shipments.

[4] Reported figure.

[5] Excludes byproduct gypsum.

[6] Includes byproduct gypsum. (In the case of Japan, series was revised to include estimates for byproduct gypsum, which represents virtually all gypsum consumed during 1976-79.)

TECHNOLOGY

A new system was patented in 1978 for anchoring mine roofbolts, using a gypsum-base cement that is cheaper than the organic resins now being used. The key ingredient in the new cementing system is specially encased water in waxy microcapsules. A free-flowing mixture of the droplets, plus dry gypsum-based cement with a chemical accelerator, is packed in sausage-shaped bags, and inserted in the hole drilled for the roofbolt. During drilling, a viscous paste is formed that hardens in 30 seconds and provides a pull strength of 8,000 pounds per foot of hole after 5 minutes.[32]

Heyward-Robinson Co. of New York, N.Y., a member of the Alusuisse Group of Switzerland, marketed in 1979 the hemihydrate process for the manufacture of wet-process phosphoric acid developed by Nissan Chemicals of Japan. The byproduct gypsum is in such a form that it can be used directly in the production of plaster and as a set-retarder in cement production.[33]

In 1978, Central Glass Co. of Japan began marketing a glass fiber-reinforced, foamed gypsum product, which is expected to find its chief usage in fireproofing walls. The product was known as Partlex, and was claimed to be light, strong, adiabatic, and easily processed on a continuous basis. Insulation properties were very attractive, with fire resistance greater than ordinary lightweight concrete, and thermal conductivity only 10% of that of concrete.[34]

Japan can utilize more of its phosphogypsum and other calcium sulfate products of chemical and utility air and water desulfurization because it concentrates on processes that produce a much purer byproduct. The new Nissan process (discussed above) yields a hemihydrate byproduct gypsum that can be recrystallized to form the dihydrate. Similarly, the Nippon Kogan Kogyo process is a hemihydrate-dihydrate process. The Central-Prayon process also involves a recrystallization stage, but dihydrate is initially formed and then dehydrated to the hemihydrate form. Although both these processes are more expensive, it means that the byproduct gypsum may be used for plaster, wallboard, and as a set-retarder in cement.[35]

In Italy, research by the Universities of Florence and Bologna in 1978 has indicated the beneficial results of a soil conditioner on heavy clay soils. A soil conditioner of calcium sulfate, ferric sulfate with minor amounts of magnesium sulfate, and ferric oxide showed increases in the permeability of clay to air and water, decreased erosion and surface crusting and cracking, and reduced costs of cultivation and equipment maintenance.[36]

American Cyanamid Co. and Lemco, Inc., came to an agreement in 1979 to process and sell the byproduct gypsum produced at Cyanamid's titanium dioxide plant in Savannah, Ga. Lemco is building a plant to produce byproduct gypsum briquettes for the cement industry in the area.[37]

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Helium

By Russell J. Foster[1]

Sales of high purity helium (minimum 99.995% purity) in the United States by the Bureau of Mines and private industry reached 811 million cubic feet in 1978, and were estimated at 817 million cubic feet in 1979.[2] High purity helium exports, all by private producers, increased to 190 million cubic feet in 1978, and an estimated 245 million cubic feet in 1979. The Bureau of Mines f.o.b. plant price for high purity helium remained at $35 per thousand cubic feet, unchanged since 1961. High purity helium sold by private producers averaged approximately $22.50 per thousand cubic feet.

Legislation and Government Programs.—A Congressionally ordered interagency helium study was completed in February 1978. The report concluded that the demand for helium is likely to increase, and the long-term rate of growth will be greatly affected by energy-related technologies. The study deemed unsound the purchase of helium for storage by the Federal Government in the short term, but recommended that policies be implemented to promote economic utilization and avoid waste, and stated that the private sector should be encouraged to extract helium from natural gas to eliminate venting helium into the atmosphere. Areas identified for further study were examined in a supplementary report issued in August 1978.

DOMESTIC PRODUCTION

Nine plants with the capacity to extract helium were operational in 1979. Seven of the plants were owned by private industry and the other two were owned by the U.S. Government and operated by the Bureau of Mines. Six extraction plants were located in Kansas, two in Texas, and one in Oklahoma.

Union Carbide Corp. began operating the world's largest helium purification and liquefaction plant at Bushton, Kans., in 1979. The $7 million facility has the capacity to liquefy 300 million cubic feet of high purity helium per year. Northern Helex Co. is providing crude helium to the plant under a long-term contract.[3]

Cities Service Helex, Inc., completed an expansion program in 1979, which has increased production capacity of high purity helium by 35% at its Ulysses, Kans., plant.[4] Western Helium Co. closed its high purity helium plant at Shiprock, N. Mex., in October 1978.

The Bureau of Mines awarded a contract in July 1979 for a pressure swing adsorption helium purification unit. This noncryogenic system has a capacity of 1 million cubic feet per day, and will be installed at the Exell, Tex., plant. High purity helium production was resumed at the Exell, Tex., plant in June 1978 to meet increased demand for helium sales and redeliveries. Installation of another helium liquefier was completed at the Bureau's Amarillo, Tex., helium plant, raising capacity to about 100 liters per hour. The unit was purchased in 1977 from Kerr-McGee Corp.'s closed Navajo, Ariz., plant.

Nondepleting helium reserves contained in natural gas of low fuel value, unusual composition, or poor location have become more attractive to natural gas producers as the price of natural gas has increased. In 1978, Mobil Oil Co. began drilling operations for potential gas production at the Tip Top field in Wyoming, the largest of the Government-owned nondepleting helium reserves. Should production capability be proven, Northwest Pipeline Corp. will purchase and upgrade the gas. Both companies have expressed a desire to cooperate with the Bureau in the possible recovery of helium. The first nondepleting reserve to be put into production was Wyoming's Table Rock field in December 1977 by Colorado Interstate Gas Co.

Table 1.—Helium extracted from natural gas in the United States

(Thousand cubic feet)

	1975	1976	1977	1978	1979p
Crude helium:[1]					
Extracted at Bureau of Mines plants	183,725	195,758	r118,760	77,301	108,946
Extracted at private industry plants	149,794	391,553	419,228	471,226	501,648
Total	333,519	587,311	r537,988	548,527	610,594
High purity helium:[2]					
Extracted at Bureau of Mines plants	184,524	177,677	219,495	221,101	235,597
Extracted at private industry plants[3]	560,899	r630,805	r727,558	779,434	826,722
Total	745,423	r808,482	r947,053	1,000,535	1,062,319
Grand total	1,078,942	r1,395,793	r1,485,041	1,549,062	1,672,913

pPreliminary. rRevised.

[1] Excludes crude helium purified after interplant transfer.

[2] Includes only those quantities produced for sale; quantities entering conservation storage system after purification are included under crude helium.

[3] Includes helium purified at the Bureau of Mines Keyes plant for the accounts of others, as follows, in thousand cubic feet:r 1975—39,396; 1976—130,356; 1977—204,948; 1978—229,512; and 1979—222,320.

Table 2.—Ownership and location of helium extraction plants in the United States, 1978-79

Category and owner or operator	Location	Product purity
Government owned:		
Bureau of Mines	Exell, Tex	Crude and high purity helium.
Do	Keyes, Okla	Do.
Private industry:		
Alamo Chemical Co.-Gardner Cryogenics Corp	Elkhart, Kans	High purity helium.
Cities Service Cryogenics, Inc	Scott City, Kans	Crude helium.[1]
Cities Service Helex, Inc	Ulysses, Kans	Crude and high purity helium.
Kansas Refined Helium Co	Otis, Kans	High purity helium.
Northern Helex Co	Bushton, Kans	Crude helium.
Phillips Petroleum Co	Hansford County, Tex	Do.
Union Carbide Corp., Linde Div	Bushton, Kans	High purity helium.
Western Helium Co.[2]	Shiprock, N. Mex	Do.

[1] Output is piped to Cities Service Helex, Inc., plant at Ulysses, Kans., for purification.

[2] Plant closed in 1978.

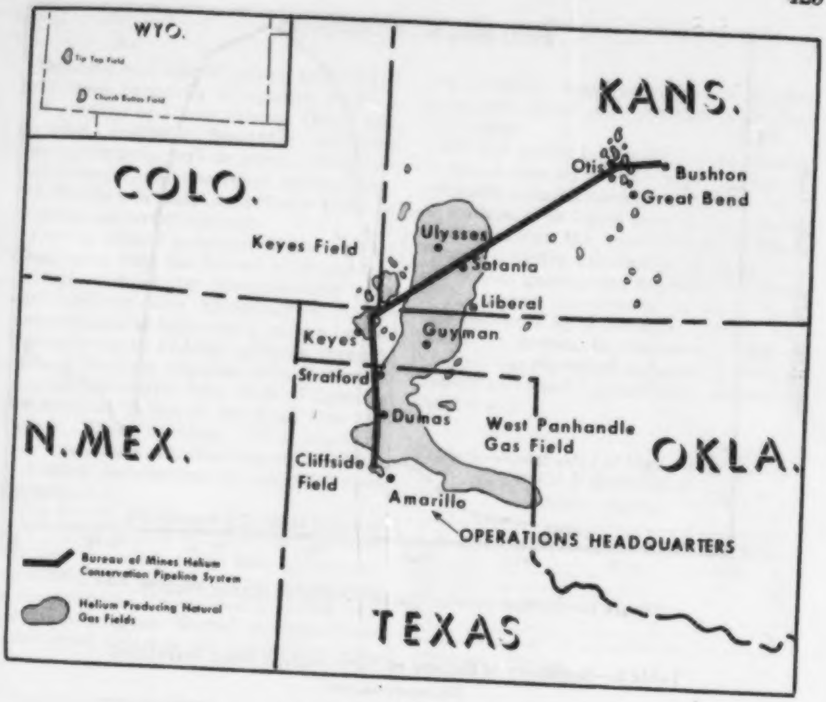
WYO.
Tip Top Field
Church Buttes Field
KANS.
COLO.
Otis
Bushton
Great Bend
Ulysses
Keyes Field
Satanta
Liberal
Keyes
Guymon
Stratford
Dumas
West Panhandle
Gas Field
N.MEX.
OKLA.
Cliffside
Field
Amarillo
OPERATIONS HEADQUARTERS
Bureau of Mines Helium
Conservation Pipeline System
Helium Producing Natural
Gas Fields
TEXAS

Figure 1.—Major U.S. helium-producing gasfields.

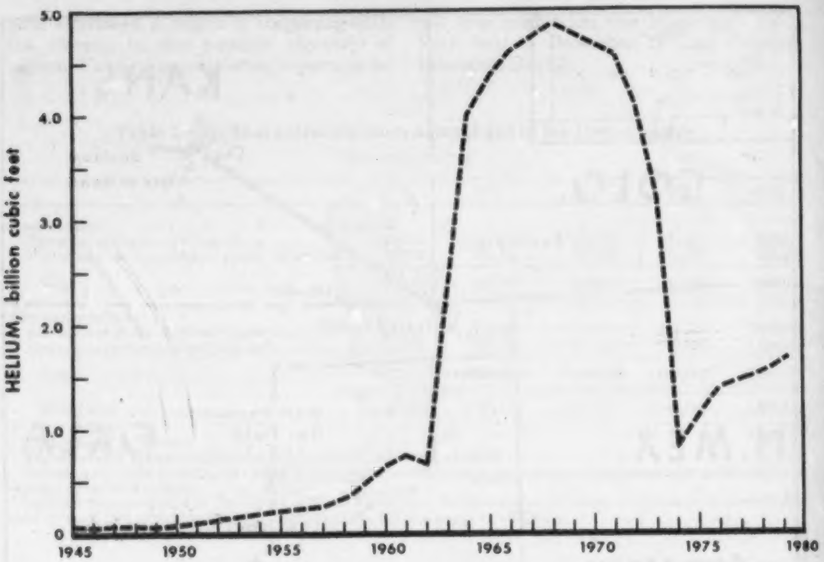

Figure 2.—Helium production in the United States, 1945-79.

Table 3.—Summary of Bureau of Mines helium plant operations

(Thousand cubic feet)

	1977	1978	1979
Supply:			
Inventory at beginning of period[1]	8,381	5,721	18,066
Helium extracted:[2]			
Exell plant:			
Crude	[r]9,807	8,801	-103,876
High purity	[r]-1,074	32,336	69,907
Total Exell plant	8,733	41,137	-33,969
Keyes plant:			
Crude	108,953	68,500	108,946
High purity[3]	218,876	195,101	165,832
Total Keyes plant	327,829	263,601	274,778
Total extracted	336,562	304,738	240,809
Helium returned in containers (net)	-5,671	4,981	-2,894
Total supply	339,272	315,440	255,981
Disposal:			
Sales of high purity helium	219,495	221,101	235,597
Net deliveries to helium conservation system[4]	114,056	76,273	4,058
Inventory at end of period[1]	5,721	18,066	16,326
Total disposal	339,272	315,440	255,981

[r] Revised.

[1] At Exell and Keyes plants and at Amarillo shipping terminal.

[2] Excludes conservation helium produced from native gas withdrawal wells at Cliffside field that have been invaded by stored helium.

[3] Excludes 204,948,000 cubic feet purified for others in 1977, 229,512,000 cubic feet in 1978, and 222,320,000 cubic feet in 1979.

[4] Excludes return of conservation helium produced as indicated in footnote 2 to conservation storage system.

CONSUMPTION AND USES

Domestic end uses of helium in 1978 and 1979 were primarily cryogenics, welding, and purging and pressurizing. Other uses included synthetic breathing mixtures, chromatography, leak detection, lifting gas, heat transfer, and controlled atmospheres. The Pacific and Gulf Coast States were the principal centers of demand.

Federal agency purchases in the form of direct sales from the Bureau of Mines constituted most of the Bureau's total high purity helium sales. Almost all of the remaining sales of high purity helium by the Bureau were to Federal agencies through General Services Administration contracts with private distributors. Federal agencies are required by law to purchase from the Bureau. These contracts make relatively small quantities of helium readily available to Federal installations at reduced freight charges.

The Bureau of Mines f.o.b. plant price of high purity helium in 1978 and 1979 was $35 per thousand cubic feet, unchanged since 1961, and maintained for the purpose of financing the Government's helium conservation program. Except in special circumstances, this was not competitive with the private producer average price of approximately $22.50 per thousand cubic feet, f.o.b. plant.

All high purity helium sold by the Bureau of Mines was shipped in gaseous form in cylinders, railroad tank cars, highway tanker trailers, or in liquid form in containerized dewars from the Amarillo helium plant. Private industry distributors shipped helium in both gaseous and liquid forms. Much of the helium transported in liquid form was delivered by semitrailer and/or containerized dewars to distribution centers where it was regasified and compressed into trailers and small cylinders for delivery to the end user.

Table 4.—Total sales of high purity helium in the United States

(Million cubic feet)

Year	Quantity
1975	601
1976	[r]634
1977	[r]779
1978	811
1979	[e]817

[e]Estimate. [r]Revised.

Table 5.—Bureau of Mines sales of high purity helium, by recipient

(Thousand cubic feet)

	1977	1978	1979
Federal agencies:			
Department of Energy	22,297	23,382	23,684
Department of Defense	114,690	119,627	114,050
National Aeronautics and Space Administration	24,694	15,464	27,555
National Weather Service	1,682	1,850	1,483
Other[1]	8,868	14,378	27,833
Total Federal agencies	172,231	174,701	194,555
Private helium distributor sales[2]	45,023	44,169	38,478
Commercial sales	2,241	2,231	2,564
Total	219,495	221,101	235,597

[1] Includes quantities used by the Bureau of Mines.

[2] Most of this was purchased by commercial firms which sold equivalent quantities to Federal installations under contract agreements with the General Services Administration.

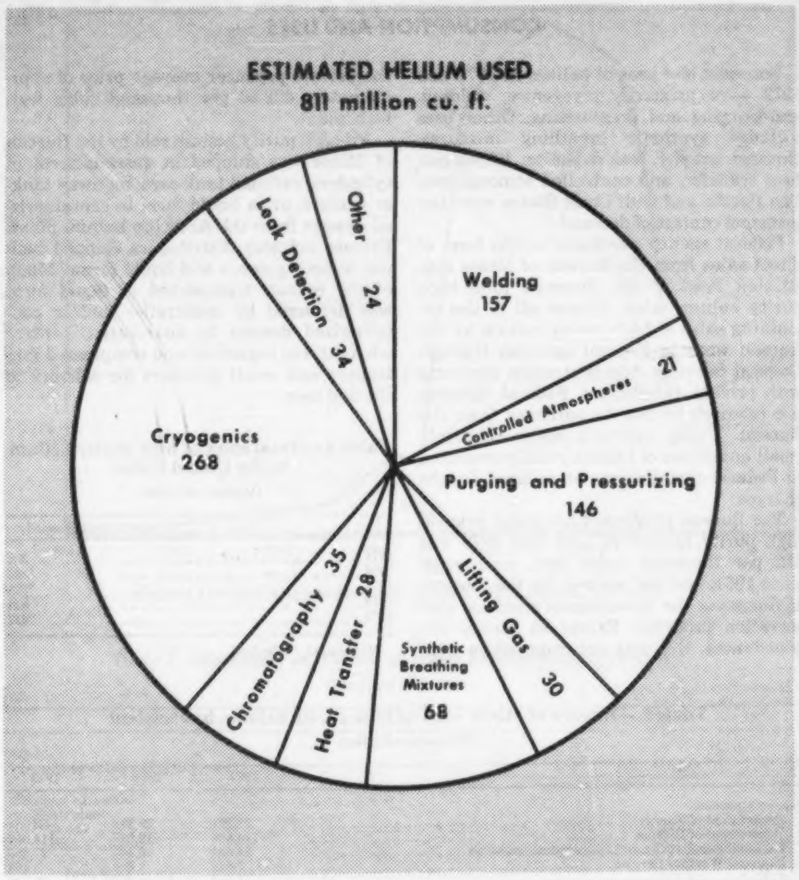

Figure 3.—Helium consumption, by end use, in the United States, 1978.

CONSERVATION

Helium held in the Bureau of Mines conservation storage system, which includes the conservation pipeline network and the Cliffside gasfield near Amarillo, Tex., totaled over 40 billion cubic feet at yearend 1979. The conservation storage system contains crude helium purchased by the Bureau of Mines under contracts entered into with four companies in 1961, and crude helium accepted between April 4 and November 12, 1973, under a court order obtained during 1973 by three of the companies. The Bureau of Mines presently stores in the conservation system helium produced in excess of sales, and private producers store helium under contract with the Bureau.

Table 6.—Summary of Bureau of Mines helium conservation system[1] operations

(Thousand cubic feet)

	1977	1978	1979
Helium in conservation storage system at beginning of period:			
Stored under Bureau of Mines conservation program[2]	37,666,363	37,780,419	37,856,692
Stored under contract for private producers' own accounts	1,424,931	1,695,010	2,031,570
Total	39,091,294	39,475,429	39,888,262
Input to system:			
Net deliveries from Bureau of Mines plants[3]	114,056	76,273	4,058
Stored under contract for private producers' own accounts	582,935	723,788	787,125
Total	696,991	800,061	791,183
Redelivery of helium stored under contract for private producers' own accounts	-312,856	-387,228	-403,160
Net addition to system	384,135	412,833	388,023
Helium in conservation storage system at end of period:			
Stored under Bureau of Mines conservation program[2]	37,780,419	37,856,692	37,860,750
Stored under contract for private producers' own accounts	1,695,010	2,031,570	2,415,535
Total	39,475,429	39,888,262	40,276,285

[1] Includes conservation pipeline system and Cliffside field.

[2] Includes helium accepted after Apr. 4, 1973, under court order.

[3] Excludes return to system of conservation helium produced from native gas withdrawal wells at Cliffside field which have been invaded by stored helium.

Table 7.—Deliveries and withdrawals of crude helium stored for private companies' own accounts in the Bureau of Mines conservation storage system

(Thousand cubic feet)

Owner	1978			1979		
	Delivered	Withdrawn	Net	Delivered	Withdrawn	Net
Cities Service Helex, Inc.	6,247	5,423	824	20,527	18,844	1,683
Northern Helex Co	274,096	--	274,096	302,188	--	302,188
Phillips Petroleum Co	211,823	65,547	146,276	226,976	72,615	154,361
Jack B. Kelley Co	--	--	--	--	1,132	-1,132
Kansas Refined Helium Co	215,025	168,353	46,672	215,025	174,623	40,402
Union Carbide Corp., Linde Div	--	63,724	-63,724	--	62,008	-62,008
Airco, Inc	--	70,940	-70,940	--	54,544	-54,544
Liquid Carbonic Corp	16,598	13,240	3,358	22,407	19,393	3,014
Total[1]	723,788	387,228	336,560	787,125	403,160	383,965

[1] Data may not add to totals shown because of independent rounding.

RESOURCES

As of January 1, 1979, domestic measured and indicated helium resources were estimated at 348 billion cubic feet. The resources included measured and indicated reserves estimated at 86 and 55 billion cubic feet, respectively, in natural gas with a minimum helium content of 0.3%. The remaining resources included 40 billion cubic feet stored in the Bureau's conservation storage system, 65 billion cubic feet of helium in measured natural gas reserves with a helium content of less than 0.3%, and 102 billion cubic feet of indicated helium in natural gas with a helium content of less than 0.3%. Of this 102 billion cubic feet, 7 billion cubic feet has been identified by individual field evaluations and is defined as indicated helium in natural gas with a helium content of 0.1% to 0.3%. The remainder is based on natural gas resource estimates provided by the Potential Gas Committee and is included here for the first time as undefined indicated resources in natural gas with a helium content of less than 0.3%. Approximately 29% of the domestic helium resources are under Federal ownership or control. Included are the Tip Top and Church Buttes fields in Wyoming, the Keyes field in Oklahoma, and the Cliffside field in Texas.

The majority of domestic helium resources are located in the midcontinent and Rocky Mountain regions of the United States. A total of 75 gasfields in 10 States contain measured and indicated helium reserves. About 83% of these reserves are located in the Hugoton field in Kansas, Oklahoma, and Texas, the Keyes field in

Oklahoma, the Panhandle and Cliffside fields in Texas, and the Tip Top field in Wyoming. Approximately 48% of the measured and indicated reserves (0.3% or greater helium content) at yearend 1978 were in currently producing gasfields. In 1978, about 22% of the helium-rich natural gas (0.3% or greater helium content) produced was processed for helium extraction. Helium in the remaining helium-rich natural gas output was dissipated incident to the consumption of the gas.

The Bureau examined a total of 369 gas samples from 16 States and 1 foreign country during 1978 in connection with its efforts to survey and identify possible new sources of helium supply. None of the samples collected and analyzed indicated the presence of major new deposits of helium.

FOREIGN TRADE

Exports of high purity helium, all by private industry, increased 13% in 1978 to 190 million cubic feet. Nearly 69% of exported helium was shipped to Europe, primarily the United Kingdom (42%), Belgium-Luxembourg (16%), and France (8%). The remaining exports were distributed as follows: North America, 11%; Asia, 10%; South America, 5%; Oceania, 3%; and Africa, 2%. Exports in 1979 were estimated at 245 million cubic feet. Continued shipments of large quantities of helium to Western Europe during 1978 and 1979 were attributed mainly to its use in the exploration for and development of oil and gas deposits, especially in the North Sea area.

Table 8.—Exports of high purity helium from the United States

(Million cubic feet)

Year	Quantity
1975	144
1976	174
1977	168
1978	190
1979	[e]245

[e]Estimate.

Source: U.S. Bureau of the Census.

WORLD REVIEW

World production of helium, excluding the United States, was estimated at 149 million cubic feet in 1978 and 181 million cubic feet in 1979. Production from a plant near Paris, France, was approximately 11 million cubic feet. The U.S.S.R. and the central economy countries of Europe produced an estimated 138 million cubic feet in 1978 and 170 million cubic feet in 1979.

In December 1979, an explosion damaged the natural gas upgrading facility, including the helium extraction plant, at Odolanow, Poland, halting production of helium. The plant will remain closed for an indefinite period.

TECHNOLOGY

A key component of an experimental superconducting generator capable of producing several times more electric power than similar models was successfully tested in 1979 by General Electric Co. Superconducting generators are more compact than conventional generators of the same capacity. Helium is required to attain temperatures near absolute zero, thus reducing the electrical resistance of certain metals, which are then subjected to a magnetic field.[5]

A prototype helium liquefier that is smaller, more efficient, and more shock resistant than existing units of the same capacity has been developed at the U.S. Naval Research Laboratory to provide a cryogenic environment for potential shipboard use of superconducting devices.[6]

The Montana Research and Development Institute is constructing a magnetohydrodynamics powerplant near Butte, Mont. After initial tests using oil, pulverized coal will be used as fuel to produce the high temperature plasma that is passed through a helium-cooled magnetic field to create an electric current.[7] The University of Tennessee received a 5-year contract from the

Department of Energy (DOE) to continue development and testing of a coal-fired flow concept for a magnetohydrodynamics system and to operate a test facility.[8]

Oak Ridge National Laboratory was named as the site of an Engineering Test Facility Design Center for fusion energy. Researchers will determine the type of fusion reactor to be designed and establish technical requirements for the components of a prototype.[9] Six helium-cooled magnets are being built for Oak Ridge's fusion program.[10] The United States and Japan initiated a joint fusion energy research program to bring a tokamak unit, operated for DOE by General Atomic Corp. at La Jolla, Calif., up to its full operating parameters, and to study its predicted advantages.[11]

Recent tests conducted over known uranium deposits by the Electric Power Research Institute have shown that measuring helium in soil and ground water can be helpful in uranium exploration. Helium is a decay product of uranium and thus can mark deep-lying ore deposits.[12]

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[1] Physical scientist, Section of Nonmetallic Minerals.

[2] All helium statistics in this chapter are in terms of contained helium measured at 14.7 pounds per square inch absolute at 70°F.

[3] Chemical Week. High on Helium. V. 122, No. 18, May 3, 1978, p. 15.

[4] Chemical Marketing Reporter. Helium Liquefaction Unit Is to Expand for Cities. V. 214, No. 23, Dec. 4, 1978, pp. 5, 45.

[5] Chemical & Engineering News. Superconducting Generator Closer to Reality. V. 57, No. 46, Nov. 12, 1979, p. 24.

[6] ———. Helium Liquefier for Shipboard Use. V. 57, No. 8, Feb. 19, 1979, p. 8.

[7] Mining Journal. Coal-Fired MHD Power Project. V. 293, No. 7509, July 20, 1979, p. 47.

[8] Chemical & Engineering News. DOE Contract Aids Tennessee's MHD Design. V. 57, No. 34, Aug. 20, 1979, p. 16.

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WORLD REVIEW

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TECHNOLOGY

[illegible]

Iron Ore

By E. C. Peterson[1] and C. T. Collins[2]

World production of iron ore in 1978 was estimated at 841 million tons,[3] slightly higher than the level of 1977. In 1979, production was estimated at 887 million tons. World trade was estimated at 335 million tons in 1978 and 370 million tons in 1979, of which about 275 million tons and 300 million tons, respectively, were oceanborne. Continued large stocks of ore holdings by producers and consumers, due to weak demand for iron ore in the world steel-producing countries, held production and trade levels down to modest gains during this period.

Production of iron ore in the United States returned to normal in 1978 following lengthy strikes by workers at major producing facilities in the Lake Superior district in 1977. Strikes in eastern Canada in 1978 reduced Canadian production and exports compared with those of 1977. This created unexpected markets for other exporters and was probably responsible for sizable gains in exports by Sweden, Brazil, and Liberia in 1978. In 1979, Canadian mining operations returned to normal and production increased about 40% over that of the previous year. The leading producing countries continued to be the U.S.S.R., Australia, Brazil, and the United States, in that order. Australia remained the leading exporter of iron ore, followed by Brazil and Canada in 1979.

Iron ore prices increased slightly in 1978, and prices continued to rise slowly on the order of 5% to 10% in 1979. Significant increases of over 30% occurred in some countries in 1979, but the average increase in value of iron ore shipments was probably about 10%. Railway and lake freight rates continued to rise in the United States. Ocean freight rates were at 1977 levels during most of 1978 but increased sharply in the latter part of that year and early in 1979. The increases were due to the high demand for bulk and combination bulk carriers in the grain and petroleum trades.

World output of iron ore pellets was estimated at 180 million tons in 1978 and about 190 million tons in 1979. Production capacity continued to increase, as new plants or expansion projects were completed in the United States, Brazil, Chile, the United Kingdom, and several other countries. World production capacity for pellets was expected to be about 280 million tons annually by the end of 1980. Direct-reduction plants were completed or under construction in several countries. Estimated world direct-reduction capacity in 1978 totaled about 12.5 million tons annually, but owing to lack of demand, operating problems, and other factors, production may have been less than half of total capacity.

The slow iron ore market and uncertainty about its recovery led to the closure of several mines in the United States and Canada, and investment in new production facilities for iron ore remained low worldwide.

In technology, a project for the production of low-Btu gas from coal, for use in pelletizing, was undertaken by the Bureau of Mines in cooperation with the Department of Energy (DOE) and 17 private companies. The Bureau's goal is to determine whether pelletizing with a coal gas of low heating value is technically feasible and practical, while DOE is interested in gasifier operations and technology. The substitution of coal for natural gas or fuel oil in iron ore pelletizing was also being studied by the Bureau and private companies.

The second United Nations Conference on Trade and Development (UNCTAD) on iron ore was held in Geneva in December 1978. Representatives of more than 40 nations attended. Agreement was reached on the establishment of an annual statistical program, in which member governments would be requested to provide statistics on iron ore from official sources. However, there was no agreement on specific problems of the iron ore industry that might be eased by international action. A third preparatory meeting was tentatively scheduled for late 1979, but was not held.

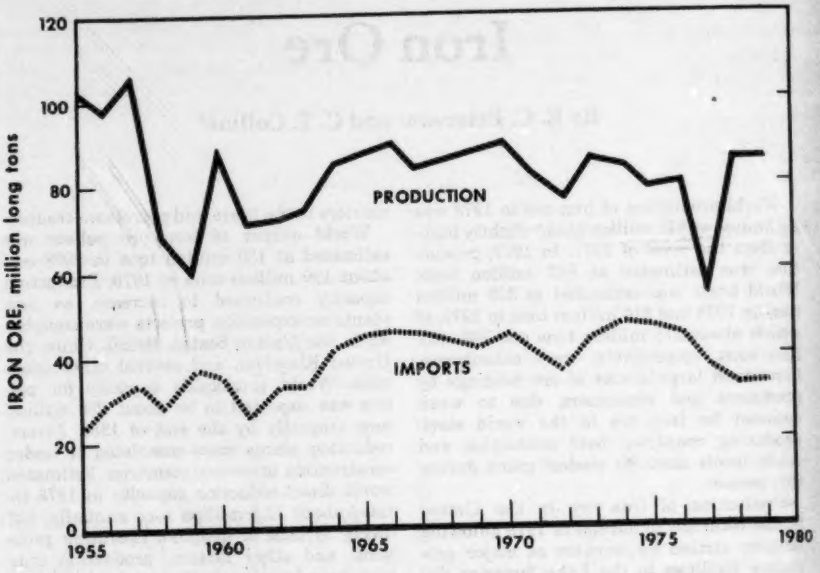

Figure 1.—United States iron ore production and imports for consumption.

Table 1.—Salient iron ore statistics

(Thousand long tons and thousand dollars)

	1975	1976	1977	1978	1979
United States:					
Iron ore (usable,[1] less than 5% manganese):					
Production[3]	78,866	79,993	55,750	81,583	85,716
Shipments	[2]75,695	[2]77,076	[2]54,053	[2]83,207	[2]86,218
Value	[2]$1,620,599	[2]$1,871,114	[2]$1,422,696	[2]$2,401,387	[2]$2,814,440
Average value at mines per ton	$21.41	$24.28	$26.32	$28.86	$32.64
Exports	2,537	2,913	2,143	4,213	5,148
Value	$60,071	$82,192	$62,760	$136,721	$178,749
Imports for consumption	46,743	44,390	37,905	33,616	33,776
Value	$860,496	$980,348	$956,584	$845,039	$923,426
Consumption (iron ore and agglomerates)	114,126	125,424	116,034	124,797	125,431
Stocks Dec. 31:					
At mines	12,299	13,993	14,811	12,359	11,266
At consuming plants	52,231	56,246	42,271	39,301	38,969
At U.S. docks	4,614	4,763	2,979	3,569	5,416
Manganiferous iron ore (5% to 35% manganese): Shipments	142	229	193	279	215
World: Production	[r]901,551	[r]868,789	[r]827,270	841,027	886,760

[r] Revised.

[1] Direct shipping ore, concentrates, agglomerates, and byproduct ore.

[2] Includes byproduct ore.

[3] Excludes byproduct ore.

EMPLOYMENT

Statistics on employment and productivity in the iron ore industry in 1978 and 1979 are shown in table 2. Employment data were supplied by the Mine Safety and Health Administration (MSHA). In table 2, statistics for all States outside the Lake Superior district were aggregated to avoid disclosure of company proprietary information.

As in previous years, statistics published in table 2 include persons employed in mines and mills but do not include persons engaged in management, research, or office work. The number of workers in those occupations averaged 1,563 in 1978 and 1,726 in 1979.

DOMESTIC PRODUCTION

U.S. mine shipments of iron ore rose more than 50% in 1978, as normal production levels were resumed following industry strikes in 1977. Production and shipments continued to rise in 1979, reflecting increased productive capacities at several locations. Virtually all crude ore production was beneficiated; direct shipping ore declined to less than 1% of total crude ore production for both years. Production of natural ore concentrates also declined as the proportion of taconite pellets continued to rise. Pellets accounted for 87% of usable production in 1978 and 88% in 1979.

In Minnesota, two new mines and three expansions boosted the State's output of taconite pellets during 1978 and 1979. United States Steel Corp. completed construction of the third expansion phase of its Minntac operations at Mountain Iron late in 1978. Completion of the expansion increased Minntac's capacity to 18.5 million tons per year and 1979 was the first full year of increased production. In 1978, Hibbing Taconite Co. completed the first full year of production at its original facilities while construction continued on an expansion to increase plant capacity to a projected 8.1 million tons annually. Production began at the expanded facilities in March 1979. Also in 1978, Inland Steel Mining Co. marked its first complete year of production at the new Minorca mine near Virginia, Minn.; the plant's capacity is 2.6 million tons annually. Eveleth Taconite Co. and Eveleth Expansion Co. marked their first full year of expanded production in 1979. The combined facilities increased Eveleth's production capacity to 6 million tons annually.

In Michigan, Cleveland-Cliffs Iron Co. completed the expansion of its Tilden project during the last quarter of 1979. Capacity at the Ishpeming operation was increased from 4 million tons to 8 million tons annually. Construction continued on the expansion at Cliff's Empire mine and plant at Palmer, which will increase annual output there to 8 million tons. Completion was scheduled for early 1980.

In mid-1979, St. Joe Lead Co. reopened the Pea Ridge underground mine and plant at Sullivan, Mo., which had been closed since December 1977. Production of pellets for use in blast furnaces and direct-reduction plants was resumed by the operator, Pea Ridge Iron Ore Co.; pellet plant capacity is 1.8 million tons annually. The company also produced magnetite concentrates for use in ferrite manufacture and heavy media for coal washing.

While new mines and pellet plant expansions increased the Nation's overall production capacity, several iron ore mines and one byproduct operation were closed during 1978 and 1979. In 1978 three mines ceased operations. Inland Steel Co. closed the Sherwood underground mine at Iron River, Mich., where a total of 13.7 million tons of ore was produced since the mine opened in 1943. The Mt. Hope Iron Mining Co., Inc., terminated operations at the Mt. Hope underground mine at Warren, N.J., after less than a year in production. The closure was reportedly due to financial problems. The historic mine previously had produced from 1710 to 1959. Jones & Laughlin Steel Corp. also closed permanently its Benson mine at Star Lake, N.Y. Previously, the company had announced that the closing was temporary.

In 1979, the country's largest underground iron mining operation ceased when Cleveland-Cliffs Iron Co. closed the Mather mine at Negaunee, Mich., and the ore improvement plant and Pioneer Pellet Plant at Eagle Mills. All operations were owned by the Negaunee Mine Co. A total of 55.7 million tons of ore was produced since the mine opened in 1943. In Minnesota, two natural ore mines were closed in 1979:

Jones & Laughlin terminated production at the Hill Annex mine at Calumet, and Shenango Furnace Co. ended production at the Whiteside mine at Buhl. The latter property was previously operated by Snyder Mining Co. Also in 1979, Cities Service Co. ceased production of byproduct iron pellets at its Copperhill complex at Ducktown, Tenn.

Construction continued during 1978 and 1979 on Reserve Mining Co.'s new on-land tailings disposal basin at Milepost 7, a site located 7 miles inland from the Silver Bay, Minn., plant. The company's other improvements included modifications at the concentrator and pelletizing plant to improve dust control, reduce particulate emissions, and upgrade the quality of their product. The pellets are expected to have an iron content of 65.8%, with 5% silica.

Late in 1979, the Minnesota State Supreme Court ruled that the tax imposed on taconite tailings discharged into State waters was unconstitutional. The court also ordered a refund of the $2 million that Reserve Mining Co. paid to the State since the 10-cent-per-ton tax was enacted in 1977. Reserve was the only company affected by the tax, due to its tailings disposal into Lake Superior.

CONSUMPTION

Consumption data are shown in tables 11 and 12. In these tables, iron ore concentrate used to produce agglomerates such as pellets or sinter at mine sites is not reported as iron ore consumed; its consumption was reported when such agglomerate was used at the furnace site (table 11). Iron ore concentrate and fines used to produce sinter at ironmaking and steelmaking plants are reported in table 12 as iron ore consumed, while consumption of agglomerates from this source is included in table 11. In table 12, the difference in weight between iron ore consumed and agglomerate produced results from the elimination of moisture as well as the addition of materials such as flue dust, mill scale, lime, and coke.

Iron ore pellets made up 62.7% of all iron ore and agglomerates consumed in 1978, and 65% in 1979. Pellets were 70% of all agglomerates consumed in 1978 and 71% in 1979. Sinter accounted for 26% of all iron ore and agglomerate consumption in both years, and natural ores accounted for the remaining 11.3% in 1978 and 9% in 1979.

Consumption of iron ore, as reported by the American Iron Ore Association (AIOA), was 116.3 million tons in 1978 and 115 million tons in 1979. The difference between these figures and those reported by the Bureau of Mines in table 11 is due mainly to different reporting procedures for sinter. The AIOA reports iron ore consumed in sintering plants at iron and steel works, while the Bureau reports the gross weight of sinter consumed in ironmaking and steelmaking furnaces. The AIOA figure thus does not include the weight of the additives such as flue dust, mill scale, slag, etc., that are used for production of sinter and constitute part of the furnace charge. The AIOA figure also does not include iron ore used for miscellaneous purposes, as listed in table 11. As a result, the AIOA annual data on consumption are usually 7% to 9% less than those reported by the Bureau.

STOCKS

Stocks of iron ore and agglomerates at U.S. mines, docks, and consuming plants totaling 55 million tons as of December 31, 1978, were nearly 5 million tons lower than those at the end of 1977, and were only slightly less than yearend stocks for 1979. Of the 42.9 million tons on hand at U.S. docks and consuming plants at the end of 1978, 50% consisted of domestic ores, 23% of Canadian ores and 27% of other foreign ores. At yearend 1979, 44.4 million tons of ore was on hand at docks and plants, consisting of 65% domestic ores, 18% Canadian ores, and 17% other foreign ores.

During 1978, monthend stocks of ore at consuming plants ranged from a low of 24 million tons in April to a high of 40 million tons in November, while those at the mines ranged from a high of 22.4 million tons in April to a low of 12.5 million tons in December. In 1979, consuming plant stocks ranged from a low of 20 million tons in April to a high of 39 million tons in November, and mine stocks ranged from a high of 26.2 million tons in April to a low of 10.7 million tons in November.

PRICES

Published prices for Lake Superior iron ores (delivered rail-of-vessel at lower lake ports) increased during 1978 and 1979. Compared with that of 1977, the increase amounted to 4% for natural ores and 10% for pellets in 1978. In 1979, prices of natural ores and pellets each rose about 10% over those of the previous year. At yearend 1979, prices for natural ores (basis 51.5% Fe, natural) were $24.56 for Mesabi non-Bessemer ore and $25.00 for Old Range non-Bessemer; prices for iron ore pellets were 67.8 cents per long ton unit (ltu). Any increases in the cost of transporting and handling, subsequent to an announcement date of a price increase, was to be borne by the buyer.

The average value (f.o.b. mine or concentrating plant) of usable iron ore shipped from domestic mines in 1979 was $32.64 per long ton, compared with $28.86 in 1978 and $26.32 in 1977. These values were calculated from producers' statements and approximated the commercial selling price less the cost of mine-to-market transportation.

Prices for Canadian and many other foreign ores increased slightly in 1978, but some declines in prices were evident. Prices rose on the order of 5% to 10% in 1979. Some larger increases were announced; however, these usually applied to long-term contracts under which prices had not changed in several years. Generally, the relatively low level of world demand and large stocks of ore held by consumers tended to keep price increases down during this 2-year period. The price of Canadian Wabush iron ore pellets, f.o.b. Pointe Noire, Quebec, in August 1978 was 52.2 cents/ltu of contained iron, an increase of about 2.2% compared with the price early in 1977. The average c.i.f. price of Norwegian iron ore exported to Western European consumers in 1979 was $25.50 per ton, about 5% below that of the previous year. Late in 1979, the major Swedish producer and exporter, Luossavaara-Kiirunavaara AB (LKAB), announced price increases of up to 30% on some iron ores under new contracts being signed with the Federal Republic of Germany consumers.

The average price of Brazilian iron ore, 65% Fe, c.i.f. North Sea ports, was reported to be about $23.50 per metric ton in 1978, up slightly from 1977. Contract prices (f.o.b.) for Brazilian pellets to West European and Japanese consumers were reportedly 44 to 45.5 cents/ltu Fe in 1978. In 1979, price increases of up to 9.5% were reported. The average f.o.b. value of Venezuelan iron ore exported to the United States, as indicated by data released by the Bureau of the Census, declined from $19.27 in 1977 to $17.65 in 1978. In 1979, the value had risen to $19.20.

Prices for foreign iron ores under most Japanese contracts in mid-1979 indicated the following ranges: For lump ore, $10.30 to $23.50 per long ton; for fines, $14.70 to $20.50; and for pellets (excluding Canada and Brazil), 34.50 to about 43 cents/ltu Fe.

TRANSPORTATION

Iron ore shipments from U.S. ports on the Great Lakes to lower lake destinations in 1978 totaled 71.3 million tons, 72% more than in 1977. The increase reflects the return to normal shipping operations following the lengthy mine strikes in 1977. In 1979, the shipments totaled 74.7 million tons.

Lake freight rates for iron ore prevailing in 1978 and 1979 (per gross ton) were as follows: From the head of the lakes to lower lake ports, $4.80 and $5.14, respectively; from Marquette, Mich., to lower lake ports, $3.95 and $4.23; and from Escanaba, Mich., to Lake Erie, $3.66 and $3.92, and to lower Lake Michigan ports, $2.87 and $3.07. The 1978 rates were about 9% higher than those in 1977.

Rail freight rates for iron ore increased about 9% in 1978 compared with the previous year's rates. Published rates in effect in 1978 and 1979 included the following (per gross ton): From the Mesabi Range to Duluth-Superior, $3.37 and $3.74, respectively; Mesabi Range to Pittsburgh district, $24.02 and $26.90; Black River Falls (Wis.) to Chicago, $4.99 and $5.59; Lake Erie ports to Pittsburgh and Wheeling districts, $6.31 and $6.81; Baltimore to Pittsburgh, $9.26 and $10.00; and Winton Junction (Wyo.) to Geneva, Utah, $4.62 and $4.91.

The trend toward use of larger ore-carrying vessels and automation of unloading systems continued on the U.S. Great

Lakes as well as in oceanborne trade.

On the Great Lakes four new 1,000-foot self-unloading ore carriers were put into service. In June 1978, Bethlehem Steel Corp.'s *Lewis Wilson Foy* began service. In October, the *George A. Stinson*, a 59,000-gross-ton cargo carrier, owned by National Steel Corp., began service. Early in 1979, the *Edwin H. Gott*, a 61,000-ton vessel owned by United States Steel Corp., made its maiden voyage. In August, the carrier, *Indiana Harbor*, operated by the American Steamship Co., began service. The carrier was the eighth 1,000-foot vessel to begin service on the Great Lakes since 1971. Several other carriers of this type were either under construction or planned to start service in the early 1980's.

During mid-May 1979, the *Mv. James R. Barker* of the Interlake Steamship Co. fleet established a new record for the largest single cargo ever carried on the Great Lakes. A total of 61,293 gross tons of iron ore pellets was loaded at the Chicago and Northwestern Railway dock in Escanaba, Mich.

New port facilities were completed by yearend 1978 at Superior, Wis., and Two Harbors, Minn. At Superior, Burlington-Northern Railway raised its annual ore-handling and shipping capacity to 18 million tons compared with about 8 million tons previously, and ore storage capacity was increased to more than 5 million tons. Cost of this project was reportedly $70 million. At Two Harbors, the Duluth, Missabe & Iron Range Railway increased its ore loading capacity to a reported 27 million tons per year at a cost of $35 million. Construction on Republic Steel Corp.'s new $20 million iron ore transfer terminal at Lorain, Ohio, continued on schedule. The facility is scheduled to be completed by the 1980 shipping season. All three of these port developments are designed to accomodate 1,000-foot carriers.

Completion or improvements in the capacity of foreign iron ore shipping and receiving ports to accomodate larger ore carriers were reported. The port of Narvik (Norway), through which most Swedish iron ore exports are shipped, completed an expansion program and can now handle carriers of up to 350,000 deadweight tons (dwt). The port of Saldanha Bay (the Republic of South Africa) was capable of loading 250,000-dwt carriers in 1978. A new offshore shipping terminal capable of handling vessels of up to 150,000 dwt was planned for Gabon, West Africa. Startup of the port is planned to coincide with completion of the Trans-Gabon Railroad currently under construction.

A 20-mile pipeline to convey slurry to a pelletizing facility in Argentina was completed in 1978 and a 40-mile line was ready for operation in western India in 1979.

In ocean shipment of iron ore, a new record for the largest single iron ore cargo ever shipped from North America occurred in May 1979, when 235,840 tons of ore was loaded at the Canadian dock terminal in Sept-Iles, Quebec. The shipment was destined for discharge at the port of Rotterdam.

In the United States, relatively shallow channel depths continued to limit incoming cargoes to about 65,000 tons.

Great Lakes rates from ports on the Gulf of St. Lawrence in Canada to Lake Erie ports remained at $3.01 per gross ton in 1978 and 1979, subject to St. Lawrence Seaway toll of 45 cents per net ton in the Montreal-Lake Ontario section. Charges of $100 per lock in the Welland Canal were paid by shipowners. The published rail freight in eastern Canada, from Schefferville to Sept-Iles, was $2.93 per gross ton in late 1979. The rail rate from Ross Bay to Sept-Iles, which affects ore shipped by Iron Ore Co. of Canada (IOC), was $2.80 per gross ton in late 1979.

Ocean freight rates for iron ore remained low through most of 1978 but increased sharply in the latter part of the year and early 1979. Reported increases ranged from less than 20% to over 100% above previous levels, and were reportedly due to increased demand for bulk and combination bulk carriers in the petroleum and grain trades. Rates published in *Metal Bulletin* for individual cargoes indicated the following charges per ton destined for European ports in late 1978 and 1979: $2.75 to $6.00 from eastern Canada; $3.00 to $6.00 from West Africa; $2.72 to $10.90 from Brazil; $4.75 to $10.50 from Western Australia; and less than $2.00 from Norway. Rates to the U.S. east coast were about $1.90 to $2.25 from eastern Canada and $4.52 to $5.30 from Brazil, while those from India to Japan were about $6.50. Ocean freight rates from Canadian ports on the Gulf of St. Lawrence to the U.S. east coast and gulf coast ports in 1978-79 were $1.50 to $1.75 per gross ton, unchanged from the 1977 rates.

The 10-year Winter Navigation Program, conducted by the U.S. Army Corps of Engineers, officially ended in September 1979.

The program was divided into two parts: A feasibility study to assess the economics and environmental effects of navigating the Great Lakes in winter, and a demonstration program to actually test engineering devices to see if winter navigation was technically possible. Since 1974, during four of the five winters in the test period, ships traversed the upper lakes all winter with the help of icebreaking ships, bubbler systems, ice booms, and steam devices to deice locks and ships. Presently, the winter navigation program is awaiting Congressional action on an amendment to the Water Resources Development Act of 1979, which would allow a limited extension of the program.

FOREIGN TRADE

Lengthy labor strikes in the Canadian iron ore industry affected both imports and exports in the United States in 1978, since about 60% of the domestic iron ore moving in and out of the country involves Canada. As a result, U.S. imports from Canada in 1978 were down about a third compared with 1977, and exports to Canada almost doubled. It appears that the strikes also created unexpected markets for other exporters and was probably responsible for increased exports by Brazil, Sweden, and Liberia in 1978.

Foreign trade worldwide was down slightly in 1978 from 1977 levels with a moderate increase in 1979. A major factor contributing to weak demand of iron ore was decreased consumption in Japan. This situation led to sharply reduced imports by Japan in 1978 and consequent cutbacks in production and exports by many suppliers, including Australia and India. World stocks of ore at producers' and consumers' yards continued high throughout 1979.

WORLD REVIEW

Argentina.—Construction continued in 1978 at the Sierra Grande iron ore project in Rio Negro Province. The 10-year project was completed in 1979 with termination of the 2.5-million-ton-per-year pelletizing plant at Punta Colorada. Pellets were first shipped from the new port facilities at Punta Colorada in September 1979. The operating company, Hierro Patagonico de Sierra Grande S.A. Minera (Hipasam), is owned by the Provincial Government and the National Development Bank, with minor Swedish interests.

Australia.—Shipments of iron ore products totaled 89 million tons in 1978 and 89.3 million tons in 1979. Exports totaled 73.9 million tons in 1978 and 77.1 million tons in 1979. Shipments of iron ore products by company were as follows (in million tons, 1978 and 1979, respectively): Mt. Newman Mining Co. Pty. Ltd., 31.8 and 31.1; Hamersley Iron Pty. Ltd., 30.7 and 29.6; Cliffs Western Australia Co. (Robe River), 12.3 and 13.0; Broken Hill Pty. Co. Ltd. (BHP), 5.8 and 7.4; Goldsworthy Mining Ltd., 6.6 and 6.9; and Savage River Mines, 2.0 and 2.2.

In 1979, the Hamersley and Mt. Newman companies each completed construction of new concentrators at properties in the Pilbara region of Western Australia. Annual production capacity will be raised by 6 million tons for Hamersley and 5 million tons for Mt. Newman. Strikes among mine and port workers for both companies in mid-1979 affected productivity for that year and offset any increase in production provided by the new concentrators.

Also in 1979, Kaiser Steel Corp. announced an agreement in principle to sell its interest in Hamersley Holdings Ltd. Conzinc Riotinto of Australia Ltd. (C.R.A.), which owns 54% of Hamersley, reportedly plans to purchase Kaiser's 28.3% share for US$207.5 million.

A new iron ore deposit was discovered at Yandicoogina in the Pilbara region in 1979. Probable reserves were reported to be more than 1 billion tons, averaging 58.7% Fe (65.2% on dry basis). CSR Ltd. announced that feasibility and market studies on development of the deposit were being carried out.

Brazil.—Exports of iron ore products increased substantially in 1978 and 1979. Nearly 65 million tons were exported in 1978, and 77.4 million tons in 1979, compared with 59 million tons in 1977. Total shipments, including those to domestic consumers, by largest producers, were (in million tons, 1978 and 1979, respectively): Companhia Vale do Rio Doce (CVRD), 52.4 and an alltime high of 62.0; Mineraçoes Brasileiras Reunidas (MBR), 13.5 and 15.1; Ferteco Mineraçao S.A., 5.9 and 6.5; S.A. Mineraçao da Trindade (SAMITRI), 5.2 and 7.1; and

Samarco Mineraçao S.A., 3.3 and 4.3.

In 1978, MBR expanded the crushing, screening, and washing facilities and doubled the stockpile capacity at its Aguas Claras mine near Belo Horizonte in Minas Gerais. Annual capacity was increased to 20 million tons of lump ore and fines for sinter and pellet feed.

In 1979, the sixth iron ore pelletizing plant at the port of Tubarao was completed. The 3-million-ton-per-year plant is a joint venture of CVRD and Instituto Nacional de Industria (INI) of Spain. Production from the new plant will go primarily to foreign markets; 60% will be consumed by Empresa Nacional Siderurgica S.A. (Ensidesa), a subsidiary of INI, under a 15-year contract.

CVRD decided to resume its plans to develop the large high-grade iron ore deposits of Serra dos Carajas, which received a setback when United States Steel Corp. withdrew from the venture in 1977. CVRD plans to raise the required capital by seeking foreign contracts for advance payment for future orders.

Canada.—Shipments of iron ore products totaled 42.3 million tons in 1978 and 58.8 million tons in 1979, including pellet shipments of 22.2 and 30.7 million tons, respectively. Shipments for export totaled 32.1 million tons in 1978 and 46.7 million tons in 1979, of which 60% was shipped to the United States in 1978 and 48% in 1979. Shipments by the largest producers were as follows (in million tons, 1978 and 1979, respectively): IOC, 17.0 and 27.4, including 10.2 and 15.3 of pellets; Quebec Cartier Mining Co. (QCM), 10.1 and 18.8 (all concentrate); and Wabush Mines, 4.3 and 5.5 (all pellets).

A 13-week strike in the first half of 1978 sharply reduced iron ore production for the year, as reflected in the above statistics. All operations of IOC and QCM were affected, as was the newly completed Sidbec-Normines Inc. pelletizing plant. Initial production at the latter facility began early in 1978 and shipments began after the strike ended in mid-June. The plant is the second of two new Sidbec-Normines pelletizing plants at Port Cartier; plant feed is concentrate produced at Lac Jeannine from crude ore mined at Fire Lake.

Several iron ore mining operations in Ontario were shut down during 1978-79. Early in 1978, Marmoraton Mining Co. Ltd., a subsidiary of Bethlehem Steel Corp., closed its Marmora iron ore mine where output of pellets totaled 10 million tons since production began in 1955.

In 1979, Steep Rock Iron Mines Ltd. ceased mining and pelletizing operations at Atikokan, and National Steel Corp. of Canada, Ltd., closed its facilities near Capreol. Caland Ore Co. Ltd. terminated its mining operations at Atikokan late in the year, with plans to close its pelletizing plant in 1980.

Chile.—Compania de Acero del Pacifico (CAP) began shipping pellets in April 1978 from its newly constructed plant at Guacolda. The 3.5-million-ton-per-year plant makes pellets from preconcentrate that is shipped 53 miles from the company's Algarrobo mine. Practically the entire output of pellets will be exported to Japan under a 10-year contract.

China, mainland.—In 1978 and 1979, three U.S. companies were awarded contracts to develop iron ore properties in mainland China. The first contract with a U.S. firm for mining engineering services was awarded to Kaiser Engineers Inc. for development of two iron ore mines. The company will develop primary crushing and transportation methods to increase production at the Nan Fen mine near the Korean border, and will develop concentrating and pelletizing facilities for the new Szechiaying mine, 300 kilometers east of Peking.

United States Steel Corp. will develop an iron ore mine and pelletizing plant at Chitashan in Liaoning Province; the project was valued at more than $1 billion. Planned capacity is 17 million metric tons of pellets and 3 million tons of concentrates annually, which will go primarily to the country's largest steel producer, Anshan Iron and Steel Co. Bethlehem Steel Corp. signed an agreement to develop mine and pelletizing facilities at Shuichang in Hopei Province. Plant capacity and overall cost of the project were not disclosed, but the value would reportedly exceed $100 million.

European Community (EC).—Community production of iron ore continued to decline in 1979, although the reduction in output was not nearly as sharp as in 1978 when production fell 10% in France, 45% in the Federal Republic of Germany, and 50% in Luxembourg, compared with that of 1977. Six mines in France and at least one each in the Federal Republic of Germany and Luxembourg were closed in 1978, as plans to reorganize production in the iron and steel industries, particularly in France, were put into effect. Total employment in the EC iron mining industries at yearend 1978 was down to 9,275, 17% less than a year earlier and almost 45% less than at the end of 1973. Exports of low-grade French ore to Belgium, Luxembourg, and the Federal Republic of Germany declined to a total of 10 million tons in 1979, about 10% less than in 1978, while imports of higher grade ores from countries outside the EC continued to increase. Imports from outside countries totaled 108.9 million tons in 1978 and were estimated at 123.8 million tons in 1979. Brazil remained the principal supplier to the EC in 1979, with about 24% of the market, followed by Sweden (15%), Canada (14%), Liberia (12%), Australia (9%), the Republic of South Africa (7%), and Mauritania (6%).

EC consumption of iron ore in 1978 totaled 149.2 million tons with an average iron content of 53%. Consumption in 1979 was estimated at 160 million tons, with the Federal Republic of Germany accounting for about one-third.

India.—Construction continued during 1978 and 1979 at the Kudremukh iron ore project in Karnataka. When completed in 1980, a high-grade concentrate will be transported via a 42-mile pipeline to a newly constructed terminal at the port of Mangalore. The Iranian Government, which previously had contracted to finance the Kudremukh project and take 7.5 million tons per year, terminated payments at the end of 1978 and sought to renegotiate the terms. The project continued with financing by the Indian Government.

In Goa, Mandovi Pellets Ltd. began production in mid-1979.

Japan.—Imports of iron ore totaled 112.8 million tons in 1978 and 128.2 million tons in 1979. The major source countries continued to be Australia, Brazil, and India. Imports from Australia, which supply 45% to 50% of Japan's iron ore, were disrupted for a 10-week period in mid-1979, owing to strikes at Mt. Newman and Hamersley mines and ports in Western Australia. Consumption of iron ore, including pellets, was reported at 107.9 million dry tons in 1978, and was estimated at 115.6 million dry tons in 1979.

The Japanese Government introduced a plan in 1978 to reduce its trade surplus and insure stable supplies of raw materials. The Government would provide loans to Japanese companies for the purchase of raw materials, including iron ore, that could be stockpiled in Japan or in the country of origin. The new pellet producer in Chile, CAP, was expected to stockpile pellets for Japan at its stockpile capacity of 800,000 tons.

Liberia.—Exports of iron ore products totaled 18 million tons in 1978 and 19.6 million tons in 1979. Shipments by company were as follows (in million tons, 1978 and 1979, respectively): Liberian-American Swedish Minerals Co. (Lamco), 10.6 and 10.1; Bong Mining Co., 7.4 and 7.1; and National Iron Ore Co., 2.4 in both years. Lamco suspended production of pellets in 1978; the company's shipments of ore increased, however, resulting in a significant reduction of stockpiled ore at the Buchanan facilities.

Mauritania.—In 1979, Kobe Steel Ltd. of Japan announced an agreement with Société Arabe des Industries Métallurgiques (Samia) of Mauritania to construct a 2-million-ton-per-year pelletizing plant at Nouadhibou. Construction was scheduled to begin in August, with completion in 1981. Pellets of 68% Fe will supply direct-reduction plants in Arab countries. Samia is a joint venture of the Mauritanian and Kuwaiti Governments.

Mexico.—Iron ore shipments reported for 1978 included 2 million tons from La Perla Minas de Fierro S.A., 1.4 million tons from La Encinas S.A., and 1.1 million tons from Consorcio Minero Peña Colorada S.A. In 1979, Peña Colorada reported a 25% increase in production. Although not reported, production by Fundidora de Monterrey S.A. was probably 1.5 million tons or more in each year. Mexico apparently continued to be essentially self-sufficient in iron ore as virtually no imports or exports of iron ore were reported. However, published Mexican iron ore statistics were too low to account for apparent demand and it was likely that production data shown in table 20 for 1978 and 1979 are about 20% too low. Mexican annual production capacity for iron ore products was about 8.5 million tons upon the completion of the expansion program at Peña Colorada in 1979.

Norway.—Near Mo-i-Rana, the Rana Mine Division of A/S Norsk Jernverk continued preparations in 1979 for opencast mining of the Ortfjell ore body, 9 to 16 kilometers north of the four open pits which now provide most of the company's crude ore supply. Ortfjell is to become the main source of ore by around 1985, and about $25 million has been spent on its development since 1974. Present operations produce about 1 million tons of hematite and magnetite concentrate per year, from 2.6 million tons of crude ore. Iron recovery, now about 70%, is expected to increase to about 85% by 1982 when installation of a Jones-type wet high-intensity magnetic separator (WHIMS) unit at the concentrator is planned for completion.

South Africa, Republic of.—Shipments of iron ore from the Sishen mine continued to increase in 1978 and 1979. In 1978, South African Iron and Steel Industrial Corp. Ltd. (ISCOR) shipped 19.1 million tons, of which 12.4 million tons was exported. In 1979, 22.5 million tons was shipped, of which 15.7 million tons was exported. Most of the ore for domestic consumption went to ISCOR's steelworks at Pretoria, Vanderbijlpark, and Newcastle.

Spain.—Cia. Andaluza di Minas S.A. (C.A.M.) shipped a record 3.1 million tons of ore in 1978 from its Marquesado mine in southern Spain. The increase in shipments was due to new stockpiling and loading facilities at the Mediterranean port of Almeria. The improvements are part of a major project to expand the company's iron ore shipments to 4.5 to 5 million tons annually in the early 1980's. Approximately two-thirds of C.A.M.'s shipments in 1978 went to the domestic steel industry and one-third was exported. Cia. Minera de Sierra Menera reported shipments of 900,000 tons of iron ore in 1978 and 1 million tons in 1979.

Sweden.—Record stocks of iron ore (nearly 15 million tons at the beginning of 1978) resulted in cutbacks of production and closure of some mines and plants in 1978, and the lowest output of iron ore from Sweden since the mid-1960's. Output of pellets (3 million tons) was about one-third of productive capacity. By midyear, however, the export market for Swedish ores improved; exports rose to 22 million tons for the year and stocks were reduced to 10 million tons. In 1979, export demand continued to rise; ore shipments increased to 30.4 million tons including 26.3 million tons of exports; pellet output rose to an estimated 6.6 million tons; and stocks of ore at yearend were down to 5.4 million tons. LKAB accounted for about 94% of Swedish exports in 1979, and the remainder came from mines in central Sweden operated by Svenskt Stål AB (SSAB). SSAB, owned 50% by the Government, was organized in 1978; it includes the iron mines and plants at Grängesberg and Strassa (formerly operated by Gränges AB), and those at Dannemora, Risberg, Blotberget, Vintjarn, and Haksberg (formerly operated by Stora Kopparbergs Bergslags AB); the latter three mines were closed by mid-1979, and operations at Risberg were scheduled to be merged with those at Grängesberg. The cold-bonded-pellet plant at Grängesberg ceased operating in 1978; shutdown of the plant, which had a capacity of 1 million tons of pellets per year, was expected to be permanent.

In other developments, LKAB began construction of a new pellet plant at Kiruna in 1979; the plant will have a production capacity of 3.5 million tons of pellets per year (half for blast furnace use and half for direct-reduction plants) and will replace the present 2-million-ton-capacity plant which was idle for most of 1979. A de-phosphorizing plant, to reduce the apatite content of high-phosphorus ores, was also being built at Kiruna.

U.S.S.R.—Exports of iron ore was estimated at 41 million tons in 1978, of which 90% was destined for East European countries, principally Poland, Czechoslovakia, and Hungary.

Soviet output of iron ore pellets was estimated at 45 million tons in 1978 and 47 million tons in 1979. Pellet production capacity is expected to be about 56.5 million tons annually by the end of 1982. In the Ukraine, construction was completed in 1979 on two additional lines to a pelletizing facility at Kremenchug. The combined production capacity of the complex is 12 million tons per year. These plants were of the grate-kiln type manufactured by Allis Chalmers Corp. of Milwaukee, Wis.

In Karelia, the Kostomus iron ore project was reportedly under construction by V/O Promashimport and a consortium of Finnish firms. The project was expected to have a production capacity of about 3 million tons per year of pellets, upon completion of the first stage of construction in 1982. Orders for four Midrex direct-reduction plants and a 2.5-million-ton-per-year pelletizing facility for 1980 startup were reportedly received in late 1977 by two Federal Republic of Germany firms. The plants are being constructed at the Soviet steel complex at Kursk. Eight additional Midrex direct-reduction plants are also reportedly to be constructed at Kursk for startup in 1984.

Venezuela.—Shipments of iron ore products increased 10% in 1978 to 13.1 million tons, and reached 13.5 million tons in 1979. Approximately 5% of shipments went to the domestic steel industry and the remainder was exported to world markets. The United States received 37% of Venezuelan exports and the rest went to Europe and to other Latin American countries. C.V.G. Ferrominera Orinoco completed construction of a new pelletizing plant with a capacity of 6.5 million tons per year. After a 2-year closure for modification and expansion, the high-iron-briquet (H.I.B.) plant at Puerto Ordaz reopened in 1979. Capacity of the plant is 640,000 tons per year of briquets with an iron content of 86.5%.

TECHNOLOGY

Technological trends in the iron ore mining industry in 1978 and 1979 continued along the lines of increasing efficiency and lowering unit costs of mining and milling, concentration, agglomeration, and transportation. The trend toward increasing use of larger mining equipment such as drills, shovels, and trucks was evident worldwide. Rotary drills capable of drilling blastholes up to 15 inches in diameter continued to increase in number, and rotary drills capable of drilling 17-1/2-inch-diameter blastholes were being tested in increasing numbers. Shovels with buckets of 24-cubic-yard capacity were in use at an Australian hematite mine. Increased use of front-end loaders with capacities of about 10 cubic yards in place of shovels for loading and cleanup operations was evident. Trucks with haulage capacities of 225 tons were being used at two large Australian mining operations; however, units of 85- to 100-ton capacity were preferred at most operations because of lower initial cost and higher operating availability.

In milling and beneficiation of iron ore, new and/or improved methods of reducing milling costs continued to be studied by the iron mining industry. These included the use of dry magnetic cobbing for improving the quality of iron ore prior to milling. A dry cobbing section will be installed in the new plant of Reserve Mining Co. in Minnesota which is scheduled to begin operation in 1980. WHIMS for concentration of hematite and goethite iron ores, and low-intensity magnetic separators for concentration of magnetic iron ore continued to be studied and tested by industry. The world's first fully automated heavy-media (HM) plant began operations in 1979 at Mt. Newman Co. Ltd.'s new beneficiation complex in Western Australia. The plant is designed for automatic startup and shutdown and operation within preset physical and process constraints. Analog loops are employed for process control.

In iron ore agglomeration, single and double deck roll screens are replacing the conventional vibrating screens in sizing of green pellet furnace feed. Blast furnace and direct-reduction operators are becoming more demanding in obtaining pellets in specified size ranges. The new screening techniques produce a furnace feed over 90% in the desired size ranges and also improve the pellets' physical properties. A double deck roll screen has been installed in the number 2 furnace line at Sidbec-Normines pelletizing facility at Port Cartier, Quebec, with excellent results.

Because of shortages of natural gas and rising cost of oil, intensive research in the use of pulverized solid fuels for induration of iron ore pellets continued. The Bureau of Mines was investigating the suitability of Western subbituminous coal and lignite for this purpose, and several iron ore producing companies were testing bituminous coals. United States Steel in their plant expansion program in Minnesota included two new pelletizing lines that can use pulverized coal for fuel. Production of low- and intermediate-Btu gas from coal, for use as pelletizing fuel, was also being investigated by the Bureau in cooperation with the Department of Energy (DOE) and private industry.

Direct-reduction of iron ore continued to grow. By yearend 1979, plants were completed or under construction in several countries, including Argentina, the Federal Republic of Germany, Trinidad-Tobago, and Venezuela. Larger direct-reduction modules having annual production capacities ranging up to 1 to 1.2 million metric tons were expected to be available in the early 1980's.

Production of direct-reduced iron in the United States continued to be limited to three plants. However, late in 1979, the operators at one of these facilities located in Portland, Oreg., announced that the plant would be shut down early in 1980 because of high natural gas prices. Only one plant was planned for construction in the United States. The feasibility of erecting a coal gasification facility incorporating an existing coal gasification process was being studied to provide fuel for the proposed plant.

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[1] Physical scientist, Section of Ferrous Metals.

[2] Mineral specialist, Section of Ferrous Metals.

[3] Unless otherwise stated, the unit of weight used in this chapter is the long ton of 2,240 pounds.

Table 2.—Employment at iron ore mines and beneficiating plants, quantity and tenor of ore produced, and average output per worker, by district and State

District and State	Average number of employees (thousands)	Worker-hours (thousands)	Crude ore (thousand long tons)	Usable ore (thousand long tons)	Iron contained[1] (thousand long tons)	Iron content (natural, percent)	Average per worker-hour: Crude ore (long tons)	Average per worker-hour: Usable ore (long tons)	Average per worker-hour: Iron contained (long tons)
1978:									
Lake Superior:									
Michigan	4	8,827	44,749	16,752	10,652	63.6	5.07	1.90	1.21
Minnesota	13	24,584	167,706	55,316	34,539	62.4	6.82	2.25	1.40
Wisconsin	(2)	495	2,067	660	431	65.3	4.18	1.33	.87
Total or average[1]	17	33,907	214,522	72,727	45,622	62.7	6.33	2.14	1.35
Other States[3]	3	5,757	19,907	8,408	4,858	57.8	3.46	1.46	.84
Grand total or average[1] [4]	20	39,664	234,428	81,135	50,480	62.2	5.91	2.05	1.27
1979:									
Lake Superior:									
Michigan	4	8,483	48,776	17,182	10,933	63.8	5.75	2.02	1.29
Minnesota	13	25,137	183,803	59,320	37,223	62.7	7.31	2.36	1.48
Wisconsin	(2)	520	2,069	698	454	65.0	3.98	1.34	.87
Total or average[1]	18	34,140	234,648	77,150	48,609	63.0	6.87	2.26	1.42
Other States[3]	3	5,890	21,176	8,255	4,831	58.5	3.60	1.40	.82
Grand total or average[1] [4]	21	40,030	255,823	85,406	53,441	62.6	6.39	2.13	1.34

[1] Data may not add to totals shown because of independent rounding.

[2] Less than 1/2 unit.

[3] Includes California, Colorado, Missouri, Montana, Nevada, New Jersey, New York, South Dakota, Texas, Utah, and Wyoming in 1978. Includes California, Colorado, Missouri, Montana, Nevada, New York, South Dakota, Texas, Utah, and Wyoming in 1979.

[4] Excludes byproduct ore.

Table 3.—Crude iron ore mined in the United States, by district, State, and variety

(Thousand long tons and exclusive of ore containing 5% or more manganese)

District and State	Number of mines	Hematite	Limonite	Magnetite	Total quantity[1]
1978:					
Lake Superior:					
Michigan	6	W	--	W	44,749
Minnesota	24	12,082	--	155,624	167,706
Wisconsin	1	--	--	2,067	2,067
Total reportable	31	12,082	--	157,691	214,522
Other States:					
Utah	4	W	--	W	4,334
Other[2]	16	868	717	13,987	15,573
Total reportable	20	868	717	13,987	19,907
Total withheld	--	22,977	--	26,106	--
Grand total[1]	51	35,928	717	197,784	234,428
1979:					
Lake Superior:					
Michigan	5	32,073	--	200,505	48,776
Minnesota	22		--		183,803
Wisconsin	1	--	--	2,069	2,069
Total reportable	28	32,073	--	202,574	234,648
Other States:					
Utah	4	--	--	3,721	3,721
Other[2]	17	607	1,542	15,306	17,455
Total reportable	21	607	1,542	19,027	21,176
Grand total[1]	49	32,680	1,542	221,601	255,823

W Withheld to avoid disclosing company proprietary data; included with "Total withheld" and "Total quantity."

[1] Data may not add to totals shown because of independent rounding.

[2] Includes California, Colorado, Missouri, Montana, Nevada, New Jersey, New York, South Dakota, Texas, and Wyoming in 1978. Includes California, Colorado, Missouri, Montana, Nevada, New York, South Dakota, Texas, and Wyoming in 1979.

Table 4.—Crude iron ore mined in the United States, by district, State, and mining method

(Thousand long tons and exclusive of ore containing 5% or more manganese)

District and State	Open pit	Underground	Total quantity[1]
1978:			
Lake Superior:			
Michigan	W	W	44,749
Minnesota	167,706	--	167,706
Wisconsin	2,067	--	2,067
Total reportable	169,773	W	214,522
Other States:			
Utah	4,334	--	4,334
Other[2]	W	W	15,573
Total reportable	4,334	W	19,907
Total withheld[3]	56,005	4,316	--
Grand total[1]	230,112	4,316	234,428
1979:			
Lake Superior:			
Michigan	W	W	48,776
Minnesota	183,803	--	183,803
Wisconsin	2,069	--	2,069
Total reportable	185,872	W	234,648
Other States:			
Utah	3,721	--	3,721
Other[2]	W	W	17,455
Total reportable	3,721	W	21,176
Total withheld[3]	62,475	3,755	--
Grand total[1]	252,068	3,755	255,823

W Withheld to avoid disclosing company proprietary data; included with "Total withheld" and "Total quantity."

[1] Data may not add to totals shown because of independent rounding.

[2] Includes California, Colorado, Missouri, Montana, Nevada, New Jersey, New York, Texas, and Wyoming in 1978. Includes California, Colorado, Missouri, Montana, Nevada, New York, South Dakota, Texas, and Wyoming in 1979.

[3] Total withheld data included with "Total quantity" for each respective district or State.

Table 5.—Crude iron ore shipped from mines in the United States, by district, State, and disposition

(Thousand long tons and exclusive of ore containing 5% or more manganese)

District and State	Direct to consumers	To beneficiating plants	Total quantity[1]
1978:			
Lake Superior:			
Michigan	W	W	44,710
Minnesota	--	168,492	168,492
Wisconsin	--	2,103	2,103
Total reportable	W	170,595	215,306
Other States:			
Utah	W	W	4,340
Other[2]	302	15,243	15,545
Total reportable[3]	302	15,243	19,885
Total withheld	1,648	47,402	--
Grand total[1]	1,951	233,240	235,191
1979:			
Lake Superior:			
Michigan	W	W	49,076
Minnesota	--	182,537	182,537
Wisconsin	--	2,047	2,047
Total reportable	W	184,584	233,660
Other States:			
Utah	W	W	3,714
Other[2]	422	16,952	17,374
Total reportable[3]	422	16,952	21,088
Total withheld	1,308	51,482	--
Grand total[1]	1,730	253,018	254,748

W Withheld to avoid disclosing company proprietary data; included with "Total withheld" and "Total quantity."

[1] Data may not add to totals shown because of independent rounding.

[2] Includes Califoria, Colorado, Missouri, Montana, Nevada, New Jersey, New York, Texas, and Wyoming in 1978. Includes California, Colorado, Missouri, Montana, Nevada, New York, South Dakota, Texas, and Wyoming in 1979.

[3] Total withheld data included with "Total quantity" for each respective district or State.

Table 6.—Usable iron ore produced in the United States, by district, State, and variety

(Thousand long tons and exclusive of ore containing 5% or more manganese)

District and State	Hematite	Limonite	Magnetite	Total quantity[1]
1978:				
Lake Superior:				
Michigan	W	--	W	16,752
Minnesota	5,497	--	49,818	55,316
Wisconsin	--	--	660	660
Total reportable[1]	5,497	--	50,478	72,727
Other States:				
Utah	W	--	W	1,962
Other[2]	608	W	5,487	[3]6,893
Total reportable[1]	608	W	5,487	[3]8,856
Total withheld	9,786	--	8,820	(4)
Grand total[1]	15,892	W	64,785	[3]81,583
1979:				
Lake Superior:				
Michigan	W	--	W	17,132
Minnesota	3,909	--	55,411	59,320
Wisconsin	--	--	698	698
Total reportable[1]	3,909	--	56,110	77,151
Other States:				
Utah	W	--	W	1,618
Other[2]	453	W	5,662	[3]6,948
Total reportable[1]	453	W	5,662	[3]8,566
Total withheld	W	W	9,207	(4)
Grand total[1]	13,904	W	70,978	[3]85,716

W Withheld to avoid disclosing company proprietary data; included with "Total withheld."

[1] Data may not add to totals shown because of independent rounding.

[2] Includes California, Colorado, Missouri, Montana, Nevada, New Jersey, New Mexico, New York, Tennessee, Texas, and Wyoming in 1978. Includes California, Colorado, Missouri, Montana, Nevada, New Mexico, New York, Tennessee, Texas, and Wyoming in 1979.

[3] Includes byproduct ore.

[4] Total withheld data included with "Total quantity," for each respective district or State.

Table 7.—Usable iron ore produced in the United States, by district, State, and type of product

(Thousand long tons and exclusive of ore containing 5% or more manganese)

District and State	Direct-shipping ore	Agglomerates	Concentrates	Iron content (natural, percent)
1978:				
Lake Superior:				
Michigan	W	W	W	64
Minnesota	--	49,487	5,829	62
Wisconsin	--	660	--	65
Total reportable	W	50,147	5,829	62
Eastern States[1] [2]	--	W	W	60
Western States[2] [3]	1,758	4,402	1,855	58
Total withheld	W	16,726	588	--
Grand total[2] [4]	W	71,276	W	62
1979:				
Lake Superior:				
Michigan	W	W	W	64
Minnesota	--	55,292	4,028	63
Wisconsin	--	698	--	65
Total reportable	W	55,990	4,028	63
Eastern States[1] [2]	--	W	W	64
Western States[2] [3]	1,408	5,190	1,773	58
Total withheld	W	17,014	273	--
Grand total[2] [4]	W	78,194	W	63

W Withheld to avoid disclosing company proprietary data.

[1] Includes New Jersey, New York, and Tennessee in 1978. Includes New York and Tennessee in 1979.

[2] Includes byproduct ore.

[3] Includes California, Colorado, Missouri, Montana, Nevada, New Mexico, South Dakota, Texas, Utah, and Wyoming in 1978. Includes California, Colorado, Missouri, Montana, Nevada, New Mexico, South Dakota, Texas, Utah, and Wyoming in 1979.

[4] Data may not add to totals shown because of independent rounding.

Table 8.—Shipments of usable iron ore from mines in the United States

(Thousand long tons and thousand dollars exclusive of ore containing 5% or more manganese)

District and State	Gross weight of ore shipped				Iron content of ore shipped				Total value[1]
	Direct-shipping ore	Agglom-erates	Concen-trates	Total quantity[1]	Direct-shipping ore	Agglom-erates	Concen-trates	Total quantity[1]	
1978:									
Lake Superior:									
Michigan	W	W	W	17,538	W	W	W	11,058	556,954
Minnesota	--	51,029	5,445	56,473	--	32,209	2,950	35,159	1,627,099
Wisconsin	--	650	--	650	--	423	--	423	W
Total reportable	W	51,678	5,445	74,661	W	32,631	2,950	46,640	2,184,053
Eastern States[2,3]	--	W	W	817	--	W	W	507	21,182
Western States:									
Utah	W	--	W	1,961	W	--	W	1,057	W
Other[3,4]	302	4,267	1,200	5,769	170	2,633	647	3,450	153,689
Total reportable[1]	302	4,267	1,200	7,729	170	2,633	647	4,507	153,689
Total withheld	1,648	W	1,022	(5)	885	W	587	(5)	42,463
Grand total[1]	1,951	73,590	7,666	83,207	1,055	46,414	4,184	51,653	2,401,387
1979:									
Lake Superior:									
Michigan	W	W	W	17,196	W	W	W	10,901	596,478
Minnesota	--	56,056	3,626	59,682	--	35,466	1,931	37,396	1,965,710
Wisconsin	--	736	--	736	--	477	--	477	W
Total reportable	W	56,792	3,626	77,614	W	35,942	1,931	48,774	2,562,188
Eastern States[2,3]	--	W	W	381	--	W	W	208	7,043

Western States:									
Utah	W	--	W	1,618	W	--	W	870	W
Other[3] [4]	422	5,135	1,049	6,606	233	3,153	582	3,968	199,014
Total reportable[1]	422	5,135	1,049	8,224	233	3,153	582	4,837	2,768,245
Total withheld	1,308	W	980	(5)	701	W	532	(5)	46,195
Grand total[1]	1,730	78,833	5,656	86,218	934	49,841	3,045	53,819	2,814,440

W Withheld to avoid disclosing company proprietary data; included with "Total withheld."

[1] Data may not add to totals shown because of independent rounding.

[2] Includes New Jersey, New York, Tennessee, and Virginia in 1978. Includes New York, Tennessee, and Virginia in 1979.

[3] Includes byproduct ore.

[4] Includes California, Colorado, Missouri, Montana, Nevada, New Mexico, South Dakota, Texas, and Wyoming in 1978. Includes California, Colorado, Missouri, Montana, Nevada, New Mexico, South Dakota, Texas, and Wyoming in 1979.

[5] Total withheld data included with "Total quantity" for each respective district or State.

Table 9.—Usable iron ore produced in Lake Superior district, by range

(Thousand long tons and exclusive after 1905 of ore containing 5% or more manganese)

Year	Marquette	Menominee	Gogebic	Vermilion	Mesabi	Cuyuna	Spring Valley	Black River Falls	Total[1]
1854-1973	417,760	313,399	320,334	103,528	2,936,828	70,336	8,149	3,520	4,173,851
1974	8,920	2,419	--	--	58,484	--	--	899	70,723
1975	12,443	2,331	--	--	51,177	--	--	784	66,735
1976	14,663	2,318	--	--	49,764	--	--	668	67,413
1977	W	W	--	--	30,943	--	--	690	43,952
1978	W	W	--	--	55,316	--	--	660	72,727
1979	W	W	--	--	59,320	--	--	698	77,151
Total[1]	498,157	327,299	320,334	103,528	3,241,832	70,336	8,149	7,919	4,572,552

W Withheld to avoid disclosing company proprietary data.

[1] Data may not add to totals shown because of independent rounding.

Table 10.—Average analyses of total tonnage[1] of all grades of iron ore shipped from the U.S. Lake Superior district

Year	Quantity (thousand long tons)	Content (percent)[2]					
		Iron	Phosphorus	Silica	Manganese	Alumina	Moisture
1974	72,194	60.26	0.030	6.66	0.35	0.40	3.94
1975	64,174	60.91	.030	6.72	.28	.39	3.53
1976	64,928	61.38	.029	6.72	.26	.43	3.20
1977	43,229	61.66	.028	6.60	.28	.44	2.90
1978	74,307	62.26	.025	6.44	.27	.40	2.61
1979	77,887	62.55	.031	6.24	.22	.35	2.61

[1] Railroad weight—gross tons.

[2] Iron and moisture on natural basis; phosphorus, silica, manganese, and alumina on dried basis.

Source: American Iron Ore Association. Iron Ore, 1979, p. 92; 1978, p. 92.

Table 11.—Consumption of iron ore and agglomerates in the United States

(Thousand long tons and exclusive of ore containing 5% or more manganese)

State	Iron ore and concentrates[1]		Agglomerates[2]		Miscellaneous[3]	Total reportable[4]
	Blast furnaces	Steel furnaces	Blast furnaces	Steel furnaces		
1978:						
Alabama, Kentucky, Texas	1,663	W	7,489	--	W	9,152
California, Colorado, Utah	1,764	W	5,545	W	W	7,310
Ohio and West Virginia	2,244	139	21,412	22	W	23,817
Illinois, Indiana, Michigan	919	--	45,106	W	W	46,024
Maryland, New York, Pennsylvania	5,516	299	31,158	366	W	37,339
Undistributed	--	140	--	77	938	1,155
Total[4]	12,106	578	110,711	465	938	124,797
1979:						
Alabama, Kentucky, Texas	725	W	8,738	W	W	9,463
California, Colorado, Utah	1,585	W	5,964	W	W	7,549
Ohio and West Virginia	1,492	99	21,860	W	W	23,452
Illinois, Indiana, Michigan	964	--	43,531	91	W	44,586
Maryland, New York, Pennsylvania	4,347	254	34,101	100	W	38,802
Undistributed	--	75	--	503	1,001	1,580
Total[4]	9,113	429	114,194	694	1,001	125,431

W Withheld to avoid disclosing company proprietary data; included in "Undistributed."

[1] Not including pellets or other agglomerated products.

[2] Includes 64.6 million tons of pellets produced at U.S. mines and 13.7 million tons of foreign pellets in 1978; includes 68.2 million tons of pellets produced at U.S. mines and 13.7 million tons of foreign pellets in 1979.

[3] Includes iron ore consumed in production of cement and ferroalloys, and iron ore shipped for use in manufacture of paint, ferrites, and heavy media.

[4] Data may not add to totals shown because of independent rounding.

Table 12.—Iron ore consumed in production of agglomerates at iron and steel plants, by State

(Thousand long tons)

State	1978		1979	
	Iron ore consumed[1]	Agglomerates produced	Iron ore consumed[1]	Agglomerates produced
Alabama, Kentucky, Texas	2,233	3,072	2,829	3,700
California, Colorado, Utah	1,899	2,210	2,016	2,250
Ohio and West Virginia	2,059	3,147	1,875	3,165
Illinois, Indiana, Michigan	5,735	10,469	5,232	9,519
Maryland, New York, Pennsylvania	9,116	13,351	7,314	13,380
Total[2]	21,042	32,249	19,267	32,013

[1] Includes domestic and foreign ores.

[2] Data may not add to totals shown because of independent rounding.

Table 13.—Beneficiated iron ore shipped from mines in the United States[1]

(Thousand long tons and exclusive of ore containing 5% or more manganese)

Year	Beneficiated ore	Total iron ore	Proportion of beneficiated to total (percent)
1974	79,995	84,985	94.1
1975	73,951	75,695	97.7
1976	74,848	76,697	97.6
1977	52,061	53,880	96.6
1978	80,875	82,826	97.6
1979	84,409	86,130	98.1

[1] Beneficiated by further treatment than ordinary crushing and screening. Excludes byproduct ore.

Table 14.—Production of iron ore agglomerates[1] in the United States, by type

(Thousand long tons)

Type	Agglomerates produced	
	1978	1979
Sinter, nodules, cinder	[2]32,397	[3]32,407
Pellets	71,128	77,799
Total[4]	103,524	110,207

[1] Production at mines and consuming plants.

[2] Includes 15,791,203 tons of self-fluxing sinter.

[3] Includes 15,558,665 tons of self-fluxing sinter.

[4] Data may not add to totals shown because of independent rounding.

Table 15.—Stocks of usable iron ore at mines,[1] Dec. 31, by district

(Thousand long tons)

District	1978	1979
Lake Superior	7,105	6,481
Other States	5,253	4,785
Total[2]	12,359	11,266

[1] Excluding byproduct ore.

[2] Data may not add to totals shown because of independent rounding.

Table 16.—Average value of usable iron ore[1] shipped from mines or beneficiating plants in the United States

(Dollars per long ton)

Type of ore	District		
	Lake Superior	Eastern	Western
1978:			
Direct-shipping, hematite and magnetite	W	--	10.75
Concentrates, hematite and magnetite	15.11	W	18.12
Concentrates, limonite	--	--	W
Agglomerates	30.73	--	29.24
1979:			
Direct-shipping, hematite and magnetite	W	--	12.05
Concentrates, hematite and magnetite	15.64	W	20.12
Concentrates, limonite	--	--	--
Agglomerates	34.31	--	32.64

W Withheld to avoid disclosing company proprietary data.

[1] F.o.b. mine or plant. Excludes byproduct ore.

Table 17.—U.S. exports of iron ore, by country

(Thousand long tons and thousand dollars)

Country	1977		1978		1979	
	Quantity	Value	Quantity	Value	Quantity	Value
Canada	2,136	62,539	4,206	136,277	5,108	177,069
France	(1)	4	(1)	5	(1)	7
Germany, Federal Republic of	(1)	1	1	46	2	162
Japan	1	16	--	--	(1)	4
Mexico	(1)	3	2	42	24	914
Norway	2	24	--	--	--	--
Taiwan	2	107	(1)	2	(1)	9
United Kingdom	(1)	3	(1)	31	3	197
Other	1	61	3	317	11	386
Total[2]	2,143	62,760	4,213	136,721	5,148	178,749

[1] Less than 1/2 unit.

[2] Data may not add to totals shown because of independent rounding.

Table 18.—U.S. imports for consumption of iron ore, by country

(Thousand long tons and thousand dollars)

Country	1977		1978		1979	
	Quantity	Value	Quantity	Value	Quantity	Value
Australia	305	5,771	264	3,935	183	2,936
Brazil	2,243	53,342	3,979	96,773	3,095	81,446
Canada	25,283	693,384	19,236	555,657	22,602	683,286
Chile	566	8,346	390	4,828	245	4,458
India	(1)	2	--	--	54	1,332
Liberia	1,792	30,226	2,170	38,737	2,190	38,112
Norway	--	--	302	6,567	44	561
Peru	1,020	35,478	818	21,629	456	14,126
South Africa, Republic of	249	5,325	94	2,949	106	2,551
Sweden	158	3,989	256	6,055	171	4,568
Tunisia	27	509	--	--	--	--
U.S.S.R	86	1,125	(1)	2	--	--
Venezuela	6,179	119,076	6,083	107,392	4,563	87,613
Other	(1)	11	23	515	65	2,437
Total[2]	37,905	956,584	33,616	845,039	33,776	923,426

[1] Less than 1/2 unit.

[2] Data may not add to totals shown because of independent rounding.

Table 19.—U.S. imports for consumption of iron ore, by customs district

(Thousand long tons and thousand dollars)

Customs district	1977		1978		1979	
	Quantity	Value	Quantity	Value	Quantity	Value
Baltimore	5,629	141,660	6,417	184,312	6,763	207,840
Buffalo	2,575	69,602	1,486	37,690	1,482	41,322
Charleston	39	920	17	921	--	--
Chicago	5,910	152,635	4,200	107,143	5,013	141,691
Cleveland	8,724	242,332	7,156	206,507	5,367	135,439
Detroit	2,224	66,286	540	10,233	668	16,255
Galveston	102	3,031	--	--	--	--
Houston	852	22,188	797	21,728	1,075	35,053
Los Angeles	217	3,872	406	6,526	695	15,388
Mobile	3,837	82,939	3,340	69,021	4,933	130,231
New Orleans	806	17,123	1,559	32,525	856	14,641
Philadelphia	6,502	140,847	7,062	153,708	6,087	164,775
Portland, Oreg	34	596	151	2,723	199	3,536
Wilmington, N.C	449	12,269	481	11,627	638	17,227
Other	3	284	4	376	(1)	27
Total[2]	37,905	956,584	33,616	845,039	33,776	923,426

[1] Less than 1/2 unit.

[2] Data may not add to totals shown because of independent rounding.

Table 20.—Iron ore, iron ore concentrates, and iron ore agglomerates: World production, by country

(Thousand long tons)

Country[1]	Gross weight[2]				Metal content[3]			
	1976	1977	1978^{p}	1979^{e}	1976	1977	1978^{p}	1979^{e}
North and Central America:								
Canada[4]	^{r}56,034	54,522	42,912	^{e}60,305	^{r}35,032	34,213	26,958	37,884
Mexico[6]	5,380	5,296	5,250	6,500	3,586	3,530	3,500	4,000
United States[7]	79,993	55,750	81,583	^{e}85,716	49,362	34,489	50,764	^{e}53,639
South America:								
Argentina	498	1,014	985	1,200	268	535	520	635
Bolivia (exports)	--	7	56	^{e}4	--	4	35	^{e}3
Brazil	92,601	80,706	83,643	86,000	60,191	52,459	54,368	55,900
Chile	9,896	7,771	9,513	--	6,088	4,802	5,857	--
Colombia	490	453	447	470	225	208	206	220
Peru	4,701	6,185	4,844	5,500	3,040	4,000	3,224	3,500
Venezuela	18,390	13,467	13,385	^{e}16,000	11,401	8,349	8,299	9,946
Europe:								
Albania[8] [9]	748	748	748	790	262	262	262	275
Austria	3,724	2,394	2,744	3,210	1,147	1,062	853	995
Belgium	62	46	42	--	19	14	13	--
Bulgaria	2,279	2,234	2,414	^{e}2,067	736	696	773	661
Czechoslovakia	1,874	1,963	1,991	^{e}1,996	^{r}564	589	597	609
Denmark	8	5	5	9	3	2	2	4
Finland[9]	1,149	1,123	1,071	^{e}1,126	^{r}756	741	700	^{e}726
France	44,467	36,051	32,930	^{e}31,168	13,574	10,875	10,157	9,614
German Democratic Republic[10]	^{r}59	62	79	70	23	25	31	21
Germany, Federal Republic of (salable)	2,220	2,458	1,575	^{e}1,618	738	810	503	516
Greece	2,170	2,017	1,659	1,840	933	952	713	791
Hungary	592	517	526	^{e}520	141	123	123	121
Italy[11]	506	471	347	^{e}215	253	198	137	^{e}87
Luxembourg	2,046	1,523	822	^{e}626	605	458	247	188
Norway	3,909	3,577	3,716	^{e}4,176	2,524	2,325	2,415	2,714
Poland	663	649	521	492	199	195	156	148
Portugal[12]	^{r}48	52	52	54	^{r}28	27	26	28
Romania	2,790	2,428	2,472	2,560	^{r}716	623	639	665
Spain[7]	^{r}8,097	8,196	8,794	9,075	^{r}4,025	4,057	4,270	4,400
Sweden	29,390	24,446	21,147	^{e}26,196	18,807	15,861	13,724	17,027
U.S.S.R	235,333	235,930	240,374	^{e}238,178	^{r}127,080	127,403	129,802	128,616
United Kingdom	4,510	3,686	4,173	4,190	^{r}1,083	885	1,002	1,005
Yugoslavia	^{r}4,202	4,381	4,492	^{e}4,522	1,475	1,490	1,572	1,590
Africa:								
Algeria	^{r}2,756	3,132	3,004	3,000	^{r}1,497	1,691	1,622	1,620
Egypt	1,223	1,387	1,433	1,475	611	693	717	740

See footnotes at end of table.

Table 20.—Iron ore, iron ore concentrates, and iron ore agglomerates: World production, by country —Continued

(Thousand long tons)

Country[1]	Gross weight[2]				Metal content[3]			
	1976	1977	1978[p]	1979[e]	1976	1977	1978[p]	1979[e]
Africa: —Continued								
Kenya[13]	[r]20	16	20	20	[r] [e]12	[r] [e]9	[e]12	12
Liberia	18,517	17,850	18,503	20,000	[r] [e]11,500	[e]11,100	[e]11,500	12,400
Mauritania	[r]9,491	9,629	6,824	7,900	6,135	6,217	4,231	4,900
Morocco	337	434	58	6	213	277	37	4
Rhodesia, Southern[6]	[r]1,870	[r]1,670	1,670	1,670	[r]1,180	[r]1,080	1,080	1,080
South Africa, Republic of[14]	15,416	26,063	23,824	[5]31,067	9,634	16,289	14,890	19,417
Swaziland	1,916	1,418	1,246	--	[r]1,030	851	748	--
Tunisia	487	338	334	334	[r]251	172	170	162
Asia:								
China:								
Mainland[6]	[r]44,300	[r]49,200	66,900	73,800	[r]22,100	[r]24,600	31,000	33,200
Taiwan	--	32	[e]32	--	--	17	[e]18	--
Hong Kong	36	--	--	--	[r]18	--	--	--
India	42,757	41,639	37,552	45,000	26,765	26,066	23,508	28,160
Indonesia	287	307	215	200	161	172	125	115
Iran[15]	[r]1,053	1,083	1,535	600	[r]643	660	935	365
Japan[16]	746	673	587	[5]449	443	435	382	183
Korea, North[6]	9,350	[r]9,550	9,850	9,850	3,740	[r]3,840	3,940	3,940
Korea, Republic of	[r]743	778	682	[5]449	[r]416	436	382	[5]284
Malaysia	308	325	315	300	185	196	192	180
Philippines	562	--	2	2	315	--	1	1
Thailand	25	62	87	[5]101	15	37	52	61
Turkey	[r]3,548	3,415	3,512	2,950	[r]1,845	1,776	1,826	1,625
Oceania:								
Australia	91,782	94,408	81,821	[5]87,594	[r]57,642	59,240	52,003	55,673
New Zealand[17]	2,435	2,728	3,709	3,600	1,388	1,555	2,114	2,050
Total	[r]868,789	827,270	841,027	886,760	492,623	469,663	473,988	502,700

[e]Estimate. [p]Preliminary. [r]Revised.

[1] In addition to the countries listed, Cuba and Vietnam may produce iron ore, but definitive information on output levels, if any, is not available.

[2] Insofar as availability of sources permits, gross weight data in this table represent the nonduplicative sum of marketable direct shipping iron ores, iron ore concentrates, and iron ore agglomerates produced by each of the listed countries. Concentrates and agglomerates produced from imported iron ores have been excluded, under the assumption that the ore from which such materials are produced has been credited as marketable ore in the country where it was mined.

[3] Data represent actual reported weight of contained metal or are calculated from reported metal content. Estimated figures are based on latest available iron ore content reported, except for the following countries from which grades are U.S. Bureau of Mines estimates: Albania, Denmark, Hungary, Southern Rhodesia, mainland China, and North Korea.

[4] Gross weight and metal content of shipments of usable iron ore, including byproduct ore, dry tons.

[5] Reported figure.

[6] Gross weight calculated from reported iron content based on grade of 66.67% Fe.

[7] Includes byproduct ore.

[8] Nickeliferous iron ore.

[9] Includes magnetite concentrate, pelletized iron oxide (from pyrite sinter) and roasted pyrite (purple ore).

[10] Includes "roasted ore," presumably pyrite sinter, not separable from available sources.

[11] Excludes iron oxide pellets produced from pyrite sinter.

[12] Includes manganiferous iron ore.

[13] For cement manufacture.

[14] Includes byproduct magnetite as follows in thousand long tons: 1976—[r]3,412; 1977—[r]4,971; 1978—3,821; 1979—not available.

[15] Year beginning March 21 of that stated.

[16] Concentrate including concentrate derived from iron sand as follows in thousand long tons: 1976—191; 1977—124; 1978—66; 1979—not available.

[17] Largely concentrates from magnetite-titanium sands.

Iron Oxide Pigments

By Cynthia T. Collins[1]

Production and trade in finished iron oxide pigments were up in 1978, owing to continued strong demand for pigments in building materials, industrial coatings, and commercial paints. A decline in the construction and automotive industries in 1979 resulted in lower demand for pigments. Total U.S. production for the year increased, however, owing to the first full year of production by Mobay Chemical Corp. The first stage of Mobay's new synthetic iron oxide pigment plant at New Martinsville, W. Va., was completed in the third quarter of 1978. Production began late in the year, and shipments started early in 1979. The final stage of the 45,000-ton-per-year capacity plant was scheduled for completion late in 1980.

Early in 1979, Pfizer Inc. completed an expansion at its Easton, Pa., plant where production capacity for copperas red pigment was increased by 25%. Cities Service Co. formed a new subsidiary, Columbian Chemicals Co., in 1979. Production and sales of iron oxide pigments are now functions of the latter company. Capacity of the Columbian Chemicals plant at Monmouth Junction, N.J., was expanded by 20% in 1979. Chemetron Corp., a wholly owned subsidiary of Allegheny Ludlum Industries Inc., sold its Pigments Division to BASF Wyandotte Corp., the U.S. branch of the BASF AG Group of the Federal Republic of Germany. The transaction included the synthetic iron oxide pigment plant at Huntington, W. Va. In 1978 Mineral Pigments Corp. phased out production of natural iron oxide pigments made from raw materials. The company now markets only blends made from purchased pigments.

In December 1978, the Dry Color Manufacturers' Association established a committee of iron oxide pigment producers to conduct a literature search on the safety of iron oxide. The committee intends to issue a position paper for the industry and provide documentation that iron oxide is not a carcinogen.

Table 1.—Salient iron oxide pigments statistics in the United States

		1975	1976	1977	1978	1979
Mine production	short tons	43,335	66,848	59,233	84,796	87,869
Crude pigments sold or used	do	40,154	59,636	55,958	75,967	74,548
Value	thousands	$1,093	r$1,626	r$2,143	$2,799	$2,578
Iron oxides from steel plant wastes	short tons	19,252	21,408	r21,024	20,924	25,186
Value	thousands	$1,102	$1,258	r$1,644	$1,396	$1,708
Finished pigments sold	short tons	104,840	135,915	140,707	152,510	156,036
Value	thousands	$46,206	$64,506	$73,851	$81,830	$94,175
Exports	short tons	8,780	5,805	6,493	7,064	4,852
Value	thousands	$2,523	$3,353	$4,065	$6,649	$7,359
Imports for consumption	short tons	27,979	50,102	58,694	70,549	55,377
Value	thousands	$9,184	$16,554	$20,596	$24,706	$24,341

rRevised.

DOMESTIC PRODUCTION

Table 2 reflects sales data compiled from responses by 19 companies (see table 3) to the Bureau of Mines annual canvass. This represents 95% coverage of all companies that produce finished natural and/or synthetic iron oxide pigments from raw materials. The increase in production in 1979 was due to the entrance into the domestic market of Mobay Chemical Corp.'s new synthetic pigment plant in West Virginia. The gain in 1979 production was partially offset by the loss of natural oxide production from Mineral Pigments Corp.; also, a softening of demand in the last quarter of the year resulted in slight decreases in annual sales for some companies.

Domestic mine production of crude iron oxide pigments is shown in table 1, and producers are listed at the end of table 3. Cleveland-Cliffs Iron Co. closed the Mather underground iron mine at Negaunee, Mich., on July 31, 1979. Ore from the mine and associated beneficiating plants was used principally in pig iron production, but crude hematite was also shipped annually for pigments. The mine was the principal domestic producer of crude iron oxide pigments for many years.

Five steel companies produced byproduct iron oxide from plant wastes in 1978-79. Regenerated oxide from spent pickle liquor was used principally in the manufacture of ferrites, and some was used for pigments in industrial coatings. About one-third of the iron oxides derived from flue dust were used as a foundry sand additive, one-third in welding electrode manufacture, and one-third in fertilizer production.

Table 2.—Finished iron oxide pigments sold by processors in the United States, by kind

Pigment	1978		1979	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Natural:				
Black: Magnetite	10,707	$1,219	8,075	$906
Brown:				
Iron oxide[1]	8,151	2,260	10,075	3,481
Umbers:				
Burnt	5,546	2,868	4,495	2,665
Raw	2,040	936	1,782	970
Red:				
Iron oxide[2]	40,476	3,596	40,618	3,953
Sienna, burnt	665	416	647	464
Yellow:				
Ocher[3]	7,588	913	6,865	945
Sienna, raw	745	380	683	399
Total natural[4]	75,918	12,588	73,240	13,782
Synthetic:				
Brown: Iron oxide[5]	11,351	10,364	11,404	11,319
Red: Iron oxides	26,433	25,267	33,344	32,540
Yellow: Iron oxide	25,916	22,725	24,550	22,651
Other: Specialty oxides	8,969	7,951	10,291	12,053
Total synthetic[4]	72,669	66,307	79,590	78,563
Mixtures of natural and synthetic iron oxides	3,923	2,935	3,205	1,830
Grand total[4]	152,510	81,830	156,036	94,175

[1] Includes Vandyke brown.
[2] Includes pyrite cinder.
[3] Includes yellow iron oxide.
[4] Data may not add to totals shown because of independent rounding.
[5] Includes synthetic black iron oxide.

Table 3.—Producers of iron oxide pigments in the United States in 1978-79

Producer	Mailing address	Plant location
Finished pigments:		
BASF Wyandotte Corp	100 Cherry Hill Rd. Parsippany, N.J. 07054	Wyandotte, Mich.; Huntington, W. Va.
Blue Ridge Talc Co., Inc	Box 39 Henry, Va. 24102	Henry, Va.
Chemalloy Co., Inc	Box 350 Bryn Mawr, Pa. 19101	Bryn Mawr, Pa.
Cities Service Co., Columbian Div. (Became Columbian Chemicals Co. in 1979).	Box 300 Tulsa, Okla. 74102	St. Louis, Mo.; Monmouth Junction, N.J.; Trenton, N.J.
Combustion Engineering, Inc., CE Minerals Div.	901 East 8th Ave. King of Prussia, Pa. 19406	Camden, N.J.
DCS Color & Supply Co., Inc	1050 East Bay St. Milwaukee, Wis. 53207	Milwaukee, Wis.
E. I. du Pont de Nemours & Co., Inc.	Pigments Dept. Wilmington, Del. 19898	Newark, N.J.
Ferro Corp., Ottawa Chemical Div.	700 North Wheeling St. Toledo, Ohio 43605	Toledo, Ohio.
Foote Mineral Co	Route 100 Exton, Pa. 19341	Exton, Pa.
Hoover Color Corp	Box 218 Hiwassee, Va. 24347	Hiwassee, Va.
Mineral Pigments Corp. (Discontinued iron oxide production in 1978).	7011 Muirkirk Rd. Beltsville, Md. 20705	Beltsville, Md.
Mobay Chemical Corp.	Penn Lincoln Parkway West Pittsburgh, Pa. 15205	New Martinsville, W. Va.
New Riverside Ochre Co	Box 387 Cartersville, Ga. 30120	Cartersville, Ga.
Pfizer Inc., Minerals, Pigments & Metals Div.	235 East 42d St. New York, N.Y. 10017	Emeryville, Calif.; East St. Louis, Ill.; Easton, Pa.
Prince Manufacturing Co	700 Lehigh St. Bowmanstown, Pa. 18030	Quincy, Ill.; Bowmanstown, Pa.
Reichard-Coulston Inc	15 East 26th St. New York, N.Y.10010	Bethlehem, Pa.
George B. Smith Chemical Works, Inc.	1 Center St. Maple Park, Ill. 60151	Maple Park, Ill.
St. Joe Minerals Corp.	7733 Forsyth Blvd. Clayton, Mo. 63105	Sullivan, Mo.
Solomon Grinding Service	Box 1766 Springfield, Ill. 62705	Springfield, Ill.
Sterling Drug, Inc., Hilton-Davis Chemicals Div.	2235 Langdon Farm Rd. Cincinnati, Ohio 45237	Cincinnati, Ohio.
Crude pigments:		
Cleveland-Cliffs Iron Co., Mather Mine & Pioneer Plant (Closed July 31, 1979).	1460 Union Commerce Bldg. Cleveland, Ohio 44115	Negaunee, Mich.
Hoover Color Corp	Box 218 Hiwassee, Va. 24347	Hiwassee, Va.
St. Joe Minerals Corp. Pea Ridge Mine	7733 Forsyth Blvd. Clayton, Mo. 63105	Sullivan, Mo.
New Riverside Ochre Co	Box 387 Cartersville, Ga. 30120	Cartersville, Ga.

CONSUMPTION AND USES

Demand for iron oxide pigments in industrial coatings and building materials was strong in 1978 and continued to hold up in the first half of 1979. However, demand for pigments in those end uses declined in the latter half of the year, reflecting the downturn in the automotive and construction industries. Demand for the pigments from trade sales paints increased in 1978 and continued strong in 1979. This was due partly to the continued popularity of colors derived from iron oxides; deep browns, reds, russets, and muted golds and tans were popular shades for exterior paints.[2] Trends in interior house paints included a renewed interest in the neutral beige and tan shades, along with continued popularity of yellows, golds, and pinks.[3] A strong market for furniture in 1978 led to continued demand for sienna and some transparent oxides used in wood stains, but this market declined slightly in the last half of 1979. Use of yellow iron oxide in highway marking paints increased in some States where lead chromate pigments have been banned.

As shown in table 4, high-purity iron oxides were also consumed in a variety of other applications. They were used for their magnetic properties in the manufacture of permanent magnets, ferrites for electronic components, magnetic ink, and coatings for recording tape. Iron oxide pigments were also used as colorants in the manufacture of plastics, rubber, paper, textiles, glass, and ceramics; as a trace element in cattle feed and coloring for pet food and fertilizer; as a hot-strength binder in foundry sands; as an industrial catalyst; and as an ingredient in fluxes used in the production of welding rods and electrodes.

Table 4.—Percent of iron oxide consumption, by end use

End use	All iron oxides		Natural iron oxides		Synthetic iron oxides	
	1978	1979	1978	1979	1978	1979
Coatings (industrial finishes, trade sales paints, varnishes, lacquers)	34.0	38.0	24.0	26.0	44.0	48.0
Construction materials (cement, mortar, preformed concrete, roofing granules)	20.5	21.0	24.0	23.0	17.0	18.0
Ferrites and other magnetic and electronic applications	13.0	11.0	12.0	10.0	14.0	11.0
Colorants for plastics, rubber, paper, textiles, glass, ceramics	7.0	10.0	2.0	7.0	11.5	12.0
Industrial chemicals (such as catalysts)	8.5	7.0	7.0	6.0	9.5	9.0
Animal feed and fertilizers	9.0	8.0	18.0	17.0	1.0	1.0
Foundry sands	5.0	4.0	11.0	9.0	--	--
Other (including cosmetics and jeweler's rouge)	3.0	1.0	2.0	2.0	3.0	1.0
Total	100.0	100.0	100.0	100.0	100.0	100.0

PRICES

Prices increased in September 1978 for most natural and synthetic iron oxides. The price of micaceous iron oxide jumped 15 cents per pound, but other increases ranged from 1 cent per pound for synthetic red and Vandyke brown to 5 cents per pound for metallic and synthetic browns. Another round of price increases occurred in October and November 1979 when synthetic browns and yellows as well as Vandyke brown and ocher were raised again. Synthetic black iron oxide, unchanged since 1977, rose by more than 10 cents per pound.

Table 5.—Prices quoted on finished iron oxide pigments, per pound, bulk shipments

Pigment	December 31, 1978		December 31, 1979	
	Low	High	Low	High
Black:				
Synthetic	$0.3100	$0.3825	$0.4300	$0.4900
Micaceous	.5500	--	.5500	--
Brown:				
Ground iron ore	.1000	.1300	.1000	.1300
Metallic	.1550	.1850	.1550	.1850
Pure, synthetic	.4700	.5000	.5000	.5250
Sienna, Italian, burnt	.3400	.4850	.3400	.4850
Umber, Turkish, burnt	.2600	.2900	.2600	.2900
Vandyke brown	.2725	.3025	.3450	--
Red:				
Domestic primers	.2025	.2325	.2025	.2325
Pure, synthetic	.4350	.4650	.4350	.4650
Spanish	--	.2625	.2625	--
Yellow:				
Synthetic	.4250	.4350	.4750	.4800
Ocher, domestic	.1275	--	.1450	--

Source: American Paint Journal.

FOREIGN TRADE

In January 1978, the Tariff Schedules of the United States (TSUSA) were revised to show import breakdowns of synthetic iron oxides by color. The new categories are reflected in table 7 for 1978 and 1979. However, it is believed that some imports in the early months of 1978 were improperly classified in the "other" category because of unfamiliarity with the new breakdowns. As classifications became more accurate, the "other" category was reduced. The data for 1979 are thought to be reasonably accurate.

The reduction in imports from the Federal Republic of Germany in 1979, shown in table 8, was due largely to the onset of domestic production by Mobay Chemical Corp. Previously, the company's sales of synthetic iron oxide were imports from Mobay's parent company, Bayer AG. The drop in imports from Canada in 1979 may

Table 6.—U.S. exports of iron oxides and hydroxides, by country

Destination	1978				1979			
	Pigment grade		Other grade		Pigment grade		Other grade	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Argentina	6	$34	74	$212	13	$25	7	$8
Australia	154	207	114	308	272	337	329	799
Belgium-Luxembourg	45	67	19	20	19	103	39	43
Brazil	175	289	140	263	238	388	64	137
Canada	3,365	1,543	1,932	1,163	1,756	1,696	4,050	2,214
Colombia	37	39	73	179	41	48	12	11
Costa Rica	3	3	13	6	6	5	14	9
Denmark	55	123	31	53	46	189	3	2
Dominican Republic	2	2	19	22	9	11	7	7
Ecuador	9	12	9	19	24	36	15	36
Egypt	--	--	--	--	21	17	--	--
El Salvador	5	11	--	--	1	5	1	2
Finland	48	27	--	--	62	51	2	6
France	119	163	107	194	74	144	342	887
Germany, Federal Republic of	47	52	398	1,058	41	63	364	889
Guatemala	11	15	5	4	14	15	--	--
Hong Kong	363	386	18	22	72	78	29	45
India	8	19	22	47	1	5	12	28
Indonesia	25	65	23	72	39	118	--	--
Iran	--	--	--	--	--	--	23	13
Israel	15	6	2	1	(1)	1	--	--
Italy	582	881	65	127	289	681	218	411
Jamaica	8	11	--	--	8	22	--	--
Japan	196	526	788	1,655	206	646	1,431	3,136
Korea, Republic of	169	308	213	585	402	624	183	461
Liberia	18	14	--	--	15	14	--	--
Mexico	179	94	329	603	69	89	379	551
Netherlands	49	108	1,498	1,907	73	159	4,028	2,857
New Zealand	18	13	(1)	2	9	12	2	3
Pakistan	--	--	--	--	--	--	75	116
Philippines	18	21	--	--	38	36	--	--
Poland	10	45	--	--	--	--	3	14
Portugal	(1)	1	60	200	4	7	5	22
Seychelles	--	--	--	--	--	--	12	26
Singapore	24	23	150	230	26	45	17	56
South Africa, Republic of	31	36	(1)	5	16	31	1	3
Spain	11	18	2	6	36	45	(1)	1
Sweden	7	19	14	15	39	139	7	9
Switzerland	5	7	24	48	1	2	4	27
Taiwan	188	71	19	24	105	185	302	233
Thailand	--	--	--	--	7	6	18	21
United Kingdom	813	1,048	664	1,590	505	994	585	1,337
U.S.S.R.	--	--	407	750	--	--	--	--
Venezuela	208	286	31	40	206	227	89	68
Yugoslavia	--	--	14	24	--	--	--	--
Other	43	61	21	50	48	60	19	21
Total[2]	7,064	6,649	7,298	11,505	4,852	7,359	12,691	14,508

[1] Less than 1/2 unit.

[2] Data may not add to totals shown because of independent rounding.

Source: U.S. Bureau of the Census.

Table 7.—U.S. imports for consumption of selected iron oxide pigments

Pigment	1978 Quantity (short tons)	1978 Value (thousands)	1979 Quantity (short tons)	1979 Value (thousands)
Natural:				
Crude:				
Siennas	612	$176	287	$139
Umbers	7,970	608	6,831	615
Other	100	54	74	168
Total[1]	8,683	839	7,191	916
Finished:				
Ochers	2	(2)	3	2
Siennas	184	61	178	77
Umbers	1,393	356	736	242
Vandyke brown	951	282	798	259
Other	1,324	256	1,350	302
Total[1]	3,853	956	3,064	882
Synthetic:				
Black	16,671	1,979	9,439	1,975
Red	9,876	5,248	8,148	4,469
Yellow	9,361	5,981	12,143	8,513
Other[3]	22,104	9,703	15,390	7,587
Total[1]	58,013	22,912	45,121	22,543
Grand total[1]	70,549	24,706	55,377	24,341

[1] Data may not add to totals shown because of independent rounding.
[2] Less than 1/2 unit.
[3] Includes synthetic brown oxides, transparent oxides, and magnetic, and precursor oxides.

Source: U.S. Bureau of the Census.

Table 8.—U.S. imports for consumption of iron oxide and iron hydroxide pigments, by country

Country	Natural				Synthetic			
	1978		1979		1978		1979	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Austria	59	$31	118	$70	--	--	--	--
Belgium-Luxembourg	--	--	21	7	118	$52	252	$120
Brazil	--	--	--	--	--	--	20	4
Canada	48	10	24	10	24,377	3,403	16,614	3,388
Cyprus	8,827	735	7,268	731	5	3	--	--
France	(1)	1	(1)	2	28	76	15	25
Germany, Federal Republic of	876	243	794	277	27,674	16,736	22,122	14,882
India	--	--	20	1	--	--	--	--
Italy	481	172	405	190	--	--	(1)	2
Japan	44	46	47	141	2,786	1,328	3,059	2,792
Mexico	--	--	--	--	994	367	1,261	524
Netherlands	122	57	(1)	1	242	79	830	224
South Africa, Republic of	--	--	2	1	--	--	--	--
Spain	1,179	191	1,176	217	12	4	56	28
United Kingdom	889	304	380	152	1,779	862	891	560
Other	11	4	--	--	--	--	1	1
Total[2]	12,536	1,794	10,256	1,798	58,013	22,912	45,121	22,543

[1] Less than 1/2 unit.
[2] Data may not add to totals shown because of independent rounding.

Source: U.S. Bureau of the Census.

be due to the fact that their prices were increased to domestic levels early in the year. Imports from Canada are primarily byproduct iron oxides from regenerated steel plant pickle liquor.

According to the Bureau of the Census Schedule B, Statistical Classification of Domestic and Foreign Commodities Exported from the United States, January 1, 1978, exports shown in table 6 as "other grade" include synthetic iron hydroxide, iron oxide for catalysts, synthetic iron oxides (except pigment grade), and jeweler's rouge.

WORLD REVIEW

Table 9, showing mine production of natural iron oxide pigments by country, was adapted from table 1 in Bureau of Mines Information Circular 8813.[4] Data for the centrally planned economy countries were incomplete; therefore, no total for world mine production is shown. Data for foreign production of synthetic iron oxides were also incomplete.

Table 9.—Natural iron oxide pigments: World mine production, by country

(Short tons)

Country	1976	1977	1978[p]	1979[e]
Argentina	192	230	244	225
Australia	1,130	68	[e]55	55
Austria	11,714	10,808	11,640	11,000
Brazil	6,566	7,308	[e]7,400	7,700
Burma	679	254	508	440
Canada	--	--	--	3,000
Chile	7,651	8,979	6,132	6,600
Cyprus	11,201	13,776	14,000	13,000
Egypt	3,590	35	270	110
France	12,152	[e]12,000	[e]12,000	14,000
Germany, Federal Republic of[1]	25,177	29,124	23,672	27,500
India	101,471	83,704	80,722	82,700
Iran[2]	5,057	3,858	[e]2,200	1,100
Italy[e]	2,200	1,900	1,500	1,100
Morocco	15	39	[e]30	30
Pakistan	17,411	15,774	5,150	1,100
Paraguay	132	132	165	110
Portugal	44	68	[e]70	65
South Africa, Republic of	2,658	2,392	2,411	2,400
Spain:				
Ocher	9,902	13,630	[e]13,500	13,200
Red iron oxide	29,929	39,971	[e]26,500	27,500
United States	66,848	59,233	84,796	87,869

[e] Estimate. [p] Preliminary.
[1] Includes Vandyke brown.
[2] Iranian calendar year (March 21 to March 20), beginning in year stated.

TECHNOLOGY

The use of iron oxides for coloring is often determined by the other characteristics they possess. Because of the nontoxic nature of the oxides, they are used in plastics, paper, glass, and ceramics processed into food containers. Ceramic glazes were studied in an effort to determine the extent to which the release of silicon and boron in the glaze was a function of the coloring oxide additives. The results indicated that iron oxide pigments affect silicon and boron leaching only slightly; their effect was much less than that of chromium oxide.[5]

The divalent iron content of ferrites is important in determining their magnetic properties; therefore, an accurate method is needed for the determination of the amount of divalent iron present in large quantities of trivalent iron. A method was reported that determined the amount of divalent iron with a high degree of accuracy in many samples of NiZnCo and MnZn ferrites.[6]

Ferrites in small particles have been developed for use in the manufacture of explosives where they may enable law enforcement officials to determine illegal users. The ferrites act as magnetic tags in the explosives by identification of the temperature at which they lose their magnetism. Up to 3,000 different magnetic codes may be produced by rearrangement of the proportions of iron, zinc, and nickel in the ferrites, which results in different Curie points.[7]

Sintering of the powdered oxides is a necessary process in the manufacture of ferrites; therefore, the study of oxides during sintering is valuable in understanding their behavior. Research was reported in which the agglomeration of iron oxides during low-temperature sintering was studied. Submicrometer-size magnetic powders were monitored for surface area variations during sintering in vacuum and in air at different temperatures. In the low-temperature ranges studied (773°K, 793°K, and

843°K), it was shown that the oxidation rates of the magnetite in air altered the agglomerating time, while no phase changes were detected in vacuum-sintered powders.[8]

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[1] Mineral specialist, Section of Ferrous Metals.

[2] American Paint & Coatings Journal. Rich Colors in Nature Hues Lead 1978 Preferred List. V. 62, No. 47, May 1, 1978, pp. 49-50.

[3] American Paint & Coatings Journal. Color Likes Becoming More Conservative. V. 63, No. 8, Sept. 4, 1978, pp. 49-50.

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[4] Jolly, J. L. W., and C. T. Collins. Iron Oxide Pigments (In Two Parts). Part 2. Natural Iron Oxide Pigments—Location, Production, and Geological Description. BuMines IC 8813, 1980, 79 pp.

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[6] Gallagher, P. K. A Coulometric Analysis of Iron (II) in Ferrites Using Chlorine. Ceram. Bull., v. 57, No. 6, June 1978, pp. 576-578.

[7] Chemical & Engineering News. Magnetic Tags for Explosives Developed. V. 58, No. 3, Jan. 21, 1980, p. 26.

[8] Kramer, C. M., and R. M. German. Low-Temperature Sintering of Iron Oxides. J. Am. Ceram. Soc., v. 61, No. 7-8, July-August 1978, pp. 340-342.

Iron and Steel

By D. H. Desy[1]

In 1978-79, a world oversupply of steel prevailed, contributing to the continuation of the generally depressed condition of the world steel industry. Several countries of the European Communities (EC) restructured their steel industries with government aid, and the EC anticrisis plan was continued. Expansion of the steel industry in developing countries continued at a slower rate than previously planned. China mainland announced major expansion plans for its steel industry.

The United States produced 137.0 million tons[2] of raw steel in 1978, an improvement over 1977 production, but 9% less than the record 150.8 million tons produced in 1973. In 1979, raw steel production fell slightly below that of 1978.

Domestic prices increased by an average of about 15% in 1978 and 11% in 1979. Imports of major iron and steel products were at a record high of 22.0 million tons in 1978, but dropped to 18.4 million tons in 1979. Exports remained at about 3 million tons.

Table 1.—Salient iron and steel statistics

(Thousand short tons, unless otherwise stated)

	1975	1976	1977	1978	1979
United States:					
Pig iron:					
Production	79,721	86,848	81,494	87,690	86,975
Shipments	79,240	86,693	82,392	88,543	87,781
Annual average composite price, per ton	$187.07	$187.67	$189.57	$198.31	$203.00
Exports	60	58	51	51	105
Imports for consumption	478	415	373	655	476
Steel:[1]					
Production of raw steel:					
Carbon	100,360	112,008	108,130	116,916	116,226
Stainless	1,111	1,684	1,862	1,954	2,107
All other alloy	15,171	14,308	15,341	18,161	18,008
Total	116,642	128,000	125,333	137,031	136,341
Capability utilization (percent)[2]	76.2	80.9	78.4	86.8	87.8
Net shipments of steel mill products	79,957	89,447	91,147	97,935	100,262
Finished steel annual average composite price, cents per pound	13.102	14.213	15.577	17.957	19.984
Exports of major iron and steel products[3]	3,975	3,671	3,098	3,274	3,403
Imports of major iron and steel products[3]	12,488	15,038	19,930	22,027	18,428
World production:					
Pig iron	528,298	[r]541,177	[r]537,698	[p]558,352	[e]581,696
Raw steel (ingots and castings)	710,106	[r]742,061	[r]739,163	[p]783,415	[e]813,927

[e]Estimate. [p]Preliminary. [r]Revised.

[1] American Iron and Steel Institute (AISI).

[2] Defined by AISI as the capability to produce raw steel for a full order book based on the current availability of raw materials, fuels, and supplies, and of the industry's coke, iron, steelmaking, rolling and finishing facilities, recognizing current environmental and safety regulations.

[3] U.S. Bureau of the Census. Figures for 1978 and 1979 not strictly comparable to those of previous years.

Legislation and Government Programs.—Import quotas on specialty steel (stainless steel and alloy tool steels) which were instituted in mid-1976 were continued through 1979, and were to be eliminated by February 13, 1980. In 1978, as part of a comprehensive program for the steel industry, the Government instituted a system of trigger prices below which imports of steel products would automatically trigger an antidumping investigation. The system became effective on February 21, 1978, but imports for which the prices had been set by contract before the trigger price system went into effect were exempt until after April 30, 1978. Trigger prices were based on the production costs of Japanese steel producers, and included transportation and other importation charges. Trigger prices were revised each quarter, and were administered by the Department of the Treasury through 1979 and were to be administered by the Department of the Commerce beginning in 1980.

Under another part of the program for the steel industry, the Economic Development Administration (EDA) of the Department of Commerce, set aside $100 million, which could be used to guarantee loans of up to $550 million to medium-size steel companies for modernization, including installation of pollution control equipment. Under this program, EDA granted loan guarantees totaling approximately $370 million to six steel companies through 1979.

In 1979 the Department of the Treasury determined that 16 Brazilian firms exporting pig iron to the United States received government subsidies. The case was referred to the U.S. International Trade Commission for a determination of whether the domestic industry was injured by these imports.

Workers who were laid off from the steel industry as a result of import competition were certified as eligible to apply for trade adjustment assistance by the Department of Labor. About 109,900 workers were certified eligible from the beginning of the program in 1975 through December 31, 1979.

The Department of the Treasury reduced the minimum depreciation time for steel industry plant and equipment from 14 1/2 to 12 years, and for iron and steel foundries from 14 1/2 to 11 years, effective for property placed in service on or after August 17, 1979.

The Environmental Protection Agency (EPA) issued a regulation[3] limiting the opacity of stack emissions from basic oxygen furnaces to 10% except that an opacity of up to 20% would be permissible once during each steelmaking cycle. The regulation became effective April 13, 1978, and applied to furnaces constructed or modified after June 11, 1973. Opacity is a measure of particulate emissions.

DOMESTIC PRODUCTION

Steel production and shipments in the first quarter of 1978 were adversely affected by a coal miners' strike and severe winter weather. However, improved weather and termination of the strike in March 1978 prevented the first quarter totals from falling as low as expected. Deliveries of steel were hampered in the fourth quarter of 1978 by a strike of the Fraternal Association of Steel Haulers, which lasted for 71 days and ended on January 18, 1979.

In spite of these disruptions, steel production and shipments increased in 1978 over those of 1977. The industry produced 9.3% more raw steel and shipped 7.5% more finished steel in 1978 than it did in 1977. In 1979, raw steel production and shipments of finished steel were little changed from those of 1978. Heavy snow and low temperatures in January 1979 disrupted steel production and deliveries primarily in the Chicago area. Steel deliveries were affected by a 10-day general Teamsters' Union strike that began on April 1, 1979, and a continuation of the strike by the Teamster-affiliated steel haulers that lasted through the month of April.

Two new blast furnaces went into operation during 1978. Bethlehem Steel Corp.'s "L" furnace at the Sparrow's Point, Md., plant, which began producing iron in November 1978, is the largest blast furnace in the Western Hemisphere. It has a hearth diameter of 44.5 feet and a rated daily capacity of 8,000 tons of hot metal. It is expected to replace four older furnaces. The new blast furnace at United States Steel Corp.'s Fairfield, Ala., works, with a hearth diameter of 32 feet and a rated capacity of 5,000 tons per day, became operational in December 1978. Both furnaces utilize conveyor belt feed, have bell-less tops, and are computer controlled. In 1978, new coke oven facilities came into operation at United States Steel's Fairfield, Ala., plant and at Inland Steel Co.'s Indiana Harbor Works. The Fairfield plant, which consists of 57 ovens, 6.1 meters high with a total annual capacity of 900,000 tons, started operation in October. Inland's No. 11 coke oven battery began operation in September 1978 and consists of 69 ovens, 6 meters high, with a total annual capacity of 875,000 tons. It will provide coke for a new large blast furnace due to begin operation in 1980. Kaiser Steel Corp., at its Fontana, Calif., plant, in 1978 rebuilt its 45 oven "E" battery and restarted its No. 1 blast furnace, which had been banked for 1 1/2 years.

Lykes Corp. and LTV Corp. merged in 1978 to form one steel company from their respective divisions, Youngstown Sheet and Tube Co. and Jones & Laughlin Steel Corp. Jones & Laughlin, the surviving company, became the third largest steel company in the United States.

Republic Steel Corp. completed the first full year of operation of its two 225-ton bottom-blown basic-oxygen-process (Q-BOP) furnaces at its South Chicago works in 1978. Also in 1978, a third 200-ton Q-BOP went into operation at the Fairfield, Ala., works of United States Steel Corp., and a third 300-ton basic oxygen furnace began operation at the Burns Harbor, Ind., plant of Bethlehem Steel Corp., raising the steelmaking capacity of that plant to 5.3 million tons per year.

The world's widest continuous slab caster, installed in 1977 at National Steel Corp.'s Great Lakes Steel Division, Ecorse, Mich., completed its second year of operation in 1979. It is capable of casting a slab 104 inches wide by 12 inches thick.

Kaiser Steel Corp., Fontana, Calif., completed its modernization program with the installation of two 210-ton basic oxygen furnaces, a hot metal desulfurization unit, a continuous slab caster, computer monitoring, and pollution control equipment. Jones & Laughlin Steel Corp. began operation of two 350-ton capacity electric furnaces at its Pittsburgh, Pa., works, replacing the blast furnace and basic open hearth furnaces, which ceased operation in June 1979.

A new, 110-inch sheared plate mill went into operation at the Burns Harbor Plant of Bethlehem Steel Corp. in the first half of 1978. The expansion of the rail mill at CF & I Steel Corp., Pueblo, Colo., was completed in 1979 and will increase railmaking capacity at that plant to 550,000 tons per year.

On March 27, 1979, Wheeling-Pittsburgh Steel Corp. broke ground for the construction of a rail mill complex, the first such facility to be built in the United States in 50 years. Construction began in 1979 for installation of two 200-ton electric-arc furnaces at the Warren, Ohio, plant of Republic Steel Corp.

Minimills that began operation in 1979 included Raritan River Steel Co., at Perth Amboy, N.J., a subsidiary of Co-Steel International, Whitby, Ontario, Canada, and the newly reorganized John A. Roebling Steel Co. (Jarsco) at Roebling, N.J. Also, planned or under construction were minimills at Carnegie, Pa.; Sandusky, Ohio; Calvert City, Ky.; Monroe, Mich.; Laplace, La.; and Riverside, Utah; and expansion of capacity at several existing mills. Tennessee Forging Steel Corp. reopened its mills at Harriman, Tenn., and Newport, Ark., in 1978.

In 1979, the U.S. Army Corp of Engineers issued an environmental impact report that would permit United States Steel Corp. to begin construction of a large greenfield steel plant at Conneaut, Ohio, on Lake Erie. However, the company announced that it had no plans to proceed with construction at that time. Under the terms of the permit, construction must begin by December 1983 and be completed by December 1989.

In 1978, United States Steel Corp. closed its Central Furnaces Plant in Cleveland, Ohio, and its coking operation in Duluth, Minn. Interlake Inc. shut down its blast furnaces at Toledo, Ohio.

In 1979, Jones & Laughlin Steel Corp. indefinitely shut down a blast furnace and a blooming mill at its Indiana Harbor Works, and also shut down a blast furnace, four open hearth furnaces, and a blooming mill at its works in Youngstown, Ohio.

United States Steel Corp. announced that it would close 14 steel-related facilities and 3 cement plants at the end of 1979 and in 1980. The closings would affect 13,000 employees, reduce steel capacity by 3% to 35 million tons per year, and cause losses to the corporation estimated at $400 to $600 million. Included in the closings are the integrated steel plant at Youngstown, Ohio; several wire and wire-product plants; the plate mills at Fairfield, Ala., and Homestead, Pa.; a railroad wheel and axle plant at McKees Rocks, Pa.; three steel-fabrication plants; two container-manufacturing plants; the plant at Torrance, Calif.; and the rod mill at Pittsburg, Calif.

Minimills that shut down include Pacific States Steel Corp., Union City, Calif., in 1978; and New Jersey Steel and Structural Corp., Sayreville, N.J. and Yale Steel Corp., Wallingford, Conn., in 1979.

Oregon Steel Mills Division of Gilmore Steel Corp., Portland, Oreg., announced that its Midrex-process direct-reduction plant would be shut down early in 1980, citing the increased cost of natural gas from

Canada used in the process. The steel mill will continue operations using only scrap as the ferrous raw material.

Materials Used in Ironmaking.—Materials used in ironmaking are shown in tables 3 and 6. Domestic pellets charged to blast furnaces totaled 72.2 million tons in 1978 and 76.1 million tons in 1979, and sinter charged was 35.8 million tons in 1978 and 35.9 million tons in 1979. Pellets and other agglomerates from foreign sources amounted to 15.9 million tons in 1978 and 16.3 million tons in 1979. In 1978, a total of 23.6 million tons of iron ore was consumed by agglomerating plants at or near blast furnaces in producing 36.1 million tons of agglomerates. In 1979, the figures were 21.6 million tons and 35.9 million tons, respectively. Other materials consumed by agglomerating plants in 1978 were 4.1 million tons of mill scale, 2.3 million tons of flue dust, 2.9 million tons of slag, 2.0 million tons of coke breeze, 137,000 tons of anthracite and 9.0 million tons of fluxes. In 1979 4.3 million tons of mill scale, 2.3 million tons of flue dust, 2.9 million tons of slag, 1.9 million tons of coke breeze, 130,000 tons of anthracite, and 9.1 million tons of fluxes were consumed by agglomerating plants.

Blast furnace oxygen consumption in 1979 totaled 35.1 billion cubic feet, compared with 35.6 billion cubic feet in 1978, according to the American Iron and Steel Institute (AISI). Blast furnaces, through tuyere injection, consumed 14.6 billion cubic feet of natural gas; 4.7 billion cubic feet of coke oven gas; 563 million gallons of oil; 101 million gallons of tar, pitch, and miscellaneous fuels; 128,000 tons of bituminous coal; and 8,000 tons of anthracite in 1978. In 1979, the materials consumed in the blast furnace through tuyere injection consisted of 30.2 billion cubic feet of natural gas; 6.3 billion cubic feet of coke oven gas; 608 million gallons of oil; 110 million gallons of tar, pitch, and miscellaneous fuels; and 97,000 tons of bituminous coal.

Materials Used in Steelmaking.—In addition to the materials shown in tables 8 and 9, steelmaking furnaces according to AISI consumed 0.7 million tons of fluorspar, 1.3 million tons of limestone, 8.3 million tons of lime, and 1.2 million tons of other fluxes in 1978. Consumption was 0.6 million tons of fluorspar, 1.3 million tons of limestone, 8.2 million tons of lime, and 1.2 million tons of other fluxes in 1979. Oxygen consumption in steelmaking totaled 203.7 billion cubic feet in 1978 and 202.4 billion cubic feet in 1979.

Metalliferous materials consumed in domestic steel furnaces in 1978, per ton of raw steel produced, averaged 1,220 pounds of pig iron, 1,027 pounds of scrap, 25 pounds of ferroalloys, and 17 pounds of ore and agglomerates. In 1979, 1,202 pounds of pig iron, 1,032 pounds of scrap, 25 pounds of ferroalloys, and 18 pounds of ore and agglomerates were consumed per ton of steel produced.

PRICES

Because of increased costs of materials and labor, steel producers raised prices on most carbon and alloy steel products by 5.5% in February and March 1978 and another 1.1% on April 1, 1978. Between July and October 1978, another increase averaging about 3% went into effect. On January 1, 1979, and on July 1, 1979, prices increased again by about 3%. Other price increases on specific products occurred during 1979. The annual average finished-steel composite price as reported in Iron Age increased 15% from 1977 to 1978 and 11% from 1978 to 1979.

Stainless steel prices varied considerably throughout 1978. On January 1, major steel producers lowered prices of four grades of flat-rolled stainless steel by 5%. In March, Allegheny Ludlum Industries Inc. first announced, then withdrew, a $9.00 per ton energy surcharge on certain specialty steels. Most producers raised prices of stainless steel bars and wire by 4% effective April 3, 1978. In June and July, prices of stainless steel sheet and strip, including type 409, which is used in automobile catalytic converters, were raised by 4.5% to 5%. Citing industrywide discounting, Allegheny Ludlum Industries Inc. reduced list prices of stainless steel plate by 15%, effective July 12, 1978. During October 1978, prices of stainless steel bars, wire, and plate increased 4% to 6%.

Stainless steel price increases averaged 8% to 9% during 1979. In addition, during 1978 and 1979, some producers added surcharges on molybdenum-containing alloy and stainless steels because of an increase in the price of molybdenum.

Iron Age reported that the composite finished-steel price rose from 16.043 cents per pound at the beginning of 1978 to 18.719

cents per pound at yearend, and in 1979 it rose from 19.549 to 20.547 cents per pound at yearend. The composite price for pig iron, according to Iron Age, rose from $191.75 per ton to $203.00 per ton in June 1978, where it remained through 1979.

FOREIGN TRADE

In 1978, the value of imports of major iron and steel products was $7.66 billion compared with exports valued at $2.29 billion, resulting in an unfavorable balance of trade of $5.37 billion. In 1979, imports totaled $7.82 billion compared with exports valued at $2.82 billion, resulting in an unfavorable balance of trade of $5.00 billion.

Between 1978 and 1979, the proportion of imports of steel mill products from Japan increased from 30.7% to 36.2%, while those from the EC decreased from 35.3% to 30.9%. The actual magnitude of imports decreased from 1978 to 1979 in both cases, as did total imports.

In 1978, accelerated antidumping action was taken under the trigger price mechanism (TPM) on imports of carbon steel plate from Empresa Nacional Siderúrgica SA (Ensidesa) of Spain, Stahlexport of Poland, and China Steel Corp. of China (Taiwan). Action against Ensidesa was later dropped because only two shipments were below the trigger price. In 1979, the Department of the Treasury determined that imports from Poland and China (Taiwan) were sold at less than fair value. The U.S. International Trade Commission later determined that U.S. industry was being injured by imports of plate from China (Taiwan), but not from Poland. Other antidumping actions, not under TPM, included action against five Japanese integrated steel producers with regard to imports of carbon steel plate, which resulted in a final determination in 1978 of dumping by the Department of the Treasury. In response to a request by the Department of the Treasury, all other major pending dumping petitions in 1978 were withdrawn by the steel companies that had filed them until the effects of the trigger price mechanism could be determined. An antidumping petition filed in 1978 on imported pig iron from Brazil continued through 1979. As a result of a dumping determination on steel fasteners, tariffs were raised to 15% for a period of 3 years.

WORLD REVIEW

A continuing world oversupply of steel during 1978-79, mainly as a result of changes in the pattern of world steel production in the past 2 decades, caused several of the EC countries to reorganize their steel industries with Government aid. The EC anticrisis (Davignon) plan was continued through the period. Developing countries continued to expand their steel industries, but generally at a slower rate than previously. China mainland began an ambitious expansion program, but later reduced its immediate goals.

Argentina.—Industria Argentina de Aceros S.A. (Acindar), at Villa Constitución, 150 miles northwest of Buenos Aires, completed a major expansion project in 1978 and it was approaching its annual design capacity of 660,000 tons of billets by the end of 1979. The plant consists of a Midrex Series 400 direct-reduction module, three 110-ton electric arc furnaces, and two six-strand continuous billet casters. The Midrex unit, which started up in August 1978, utilizes a mixture of approximately 60% pellets and 30% lump ore from Brazil to produce direct-reduced iron with 93% metallization and 1.6% carbon content. The three electric arc furnaces each have a 65 megavolt ampere (Mva) transformer and operate on a mixture of 70% direct-reduced iron and 30% scrap. Water-cooled panels have been installed on the furnaces. The continuously cast billets are transferred to another part of the plant where they are rolled into a variety of products including wire rod, merchant bars, and reinforcing bars.

Belgium.—As a result of the crisis in the Belgian steel industry, the Government announced in 1978 a plan for the restructuring of the industry, including a regrouping of companies and plants; refinancing, including government part-ownership of major companies; and reduction of employment by layoffs and early retirement.

A total of approximately 6,000 wage and salary employees would be laid off, and employment further reduced by early retirement, at age 55 and above. A National Commission for Planning and Control (CNPC) was created, consisting of members from government, the steel companies, and the unions. The commission would define investment priorities and levels, determine the means of restructuring the industry, provide for common raw material purchases, and promote productivity. Plans for the restructuring were proceeding through 1979.

Brazil.—The Stage III expansion programs continued at the three major Government controlled, integrated steel companies, Companhia Siderúrgica Nacional (CSN), Companhia Siderúrgica Paulista (COSIPA), and Usinas Siderúrgica de Minas Gerais SA (Usiminas). Construction began in 1978 at the Companhia Siderúrgica de Tubarão (CST), located at Vitória, Espirito Santo, which is also the site of the major iron ore port facility and pelletizing complex of Companhia Vale do Rio Doce (CVRD). Completion is scheduled for 1982. The company was formed in 1976 by a consortium consisting of Società Finanziaria Siderúrgica (Finsider) of Italy, the Kawasaki Steel Corp. of Japan, and Siderúrgica Brasileira, S.A. (Siderbrás) of Brazil, to produce semifinished steel for finishing by the three partners. Brazil's share would be taken by CSN and COSIPA. Initial capacity was to be 3.3 million tons per year of slabs. As a result of the expansion of these and other Government-controlled steel companies, steelmaking capacity in the state sector was expected to increase from 8.3 million tons per year in 1978 to 19.7 million tons per year in 1983.

Canada.—The steel industry operated at over 90% capacity for most of 1978 and 1979. Canada introduced a benchmark price system, and began monitoring steel imports in February 1978. Steel imported at prices below the benchmark prices was subject to an accelerated dumping investigation. Imports continued to be monitored during 1979.

In December 1978, Foothills Pipelines (Yukon) Ltd. announced that The Steel Company of Canada, Ltd. (Stelco) and Interprovincial Steel and Pipe Corporation, Ltd. (IPSCO), had been chosen to supply about 1 million tons of 56-inch-diameter arctic-grade pipe for the Canadian portion of the Alaska Highway gas pipeline project.

On June 1, 1978, the Canadian Steel Industry Research Association (CSIRA) was founded to provide a medium for a joint approach to research problems by the Canadian steel industry.

Stelco continued with construction of its greenfield complex at Nanticoke, Ontario, on Lake Erie. The first phase, started in 1974, was scheduled for completion in mid-1980.

Dominion Foundries and Steel Ltd. (Dofasco) began operation in 1978 of its No. 2 basic oxygen furnace (BOF) shop, its No. 6 coke-oven battery, and eight new soaking pits at Hamilton, Ontario. The BOF shop, with one 250-ton vessel, has a capacity of 1 million tons per year. The coke-oven battery consists of 35 ovens and has a capacity of 460,000 tons per year, and the new soaking pits increased the total ingot-heating capacity to 3.3 million tons.

The Algoma Steel Corp., Ltd., Sault Ste. Marie, Ontario, rebuilt its No. 9 coke-oven battery, which became operational in November 1978. A new continuous slab caster was completed in 1979.

The expansion project at Sidbec-Dosco, Ltd., in Contrecoeur, Quebec, was completed with installation of a new continuous slab caster. This company conducted a 30-day demonstration run at its No. 2 Midrex direct-reduction unit in 1978. During the run, the unit operated at an annual rate of 880,000 tons per year, although it was rated at only 660,000 tons per year.

IPSCO, the largest pipe producer in Canada, continued with the expansion of its rolling mill at Regina, Saskatchewan, by one-third to about 825,000 tons of capacity per year. The company announced plans in 1979 to increase melting capacity from 595,000 to 825,000 tons per year.

Lake Ontario Steel Co., Ltd., of Whitby, Ontario, planned to double its steelmaking capacity to 880,000 tons per year, with the addition of one 150-ton electric arc furnace, a continuous billet caster, a reheating furnace and an additional bar mill. The project is due for completion by the autumn of 1980.

Sydney Steel Corp. (SYSCO) of Sydney, Nova Scotia, made some plant improvements during 1978, but because of continuing heavy financial losses, the firm announced that it would cut production by 25% to 30% effective November 1, 1979. Various rationalization plans were being studied during 1979 because of the continuing need to replace obsolete facilities.

Tree Island Steel Co., Ltd. (TISCO), announced plans in 1978 to construct a wire rod mill in Richmond, British Columbia. It tentatively planned to receive about 200,000 tons per year of billets from SYSCO as feed for the mill for a 10-year period starting in 1980, and to supply wire rod to TISCO's plants in Carson, Calif., and Vancouver, British Columbia.

The provincial Government of Nova Scotia announced in 1978 that it was terminating the Cansteel Corp. project, begun in 1975 to investigate the potential for a steel plant at Gabarouse Bay, Cape Breton Island, Nova Scotia, to produce 2.5 million tons per year of semifinished steel.

China, mainland.—In 1978, mainland China announced plans for a major expansion of its steel industry, including the expansion and upgrading of seven or eight existing plants and building of two or three new ones, to raise its raw steel production to 66 million tons per year in 1985. In 1979 the Chinese Government indicated that these plans were overly ambitious, and it appeared that the new goal would probably be about 50 million tons per year. One project likely to be deferred was the 10-million-ton-per-year plant planned for Chidong in Hebei Province. However, a preliminary contract was signed with Nippon Steel Corp., and ground was broken in December 1979 for a new plant at Baoshan, near Shanghai. The initial capacity of 3.3 million tons per year was expected to be attained by the end of 1982, and this was expected to be doubled by the end of 1984.

Japan remained the major exporter of iron and steel to China mainland; in 1978, exports amounted to 6.2 million tons and in 1979, 4.9 million tons.

European Communities (EC).—The steel industry of the EC remained in the depressed condition that began in 1975, and the industry operated well below capacity in 1978-79. The anticrisis (Davignon) plan was extended through 1978-79, including compulsory minimum prices on some products and voluntary guidance prices on others, to apply within the EC, as well as base prices applying to imports from outside the EC. Also included were recommended production tonnages for member countries. Bilateral trade agreements establishing quotas and import prices were negotiated with 15 countries in 1978 and extended to 18 countries in 1979.

Individual EC members continued efforts to reduce excess steelmaking capacity by closing obsolete plants and reducing the work force. Retraining and relocation of the affected employees was carried out through funding by the EC and the individual nations.

The EC drafted a set of rules under which member states could grant aid to their steel industries, if that aid would be used for modernization and restructuring of the industry without increasing its capacity. The rules were finally accepted by the member countries in December 1979.

In 1978, the EC issued a draft report of revised forecasts for the steel industry in 1980, 1985, and 1990. The report indicated that production potential for raw steel in 1980 would be between 221 and 232 million tons, whereas the average trend production would be 152 million tons, for a rate of utilization of 65.5% to 68.8%. Projected production for 1985 and 1990 under assumed high activity conditions were placed at 174 and 191 million tons, respectively. At an assumed rate of 85%, this would require a capacity of 205 million tons in 1985 and 225 million tons in 1990, which is no greater than 1978 capacity.

France.—In 1978, the French Government announced a financial rescue plan for the steel industry, under which the Government would assume a major portion of the industry's debt burden and acquire a controlling interest in the three major integrated steel companies, two of which were to be merged. By 1978, the industry had accumulated debts of $9.0 billion. In moves to rationalize the industry, 21,000 workers were to be laid off by the end of 1980 in addition to the 16,000 already laid off. The capacity of the industry would be reduced and stabilized at 25 million tons per year by 1985. The announcement of layoffs had triggered strikes and demonstrations but an agreement was reached that provided for early retirement and bonuses for workers who left voluntarily.

Germany, Federal Republic of.—During 1978-79, the steel industry began a gradual recovery from the depressed condition of 1977. A considerable part of the improvement was attributed to EC activities designed to stablilize steel prices and reduce non-EC imports. Production was somewhat reduced by a 6-week strike between November 1978 and January 1979.

Two steel companies in the Saarland were acquired by a Belgian firm, which was to restructure them with financial aid from the Federal and Saarland Governments. Capacity was to be cut by 14% and the work force cut by 50% for a loss of approximately 9,000 jobs through 1983. It was planned to establish other industries in the area to provide jobs for members affected by the layoffs.

Italy.—The Government-controlled integrated steel industry continued to experience unsatisfactory profitability and capacity utilization during 1978-79. Restructuring of the industry was being studied by the Government with the aim of reducing overcapacity and underproductivity. Since most of the Italian steel industry is modern and well located, no plant closings were anticipated. Reduction in employment was expected to occur by attrition rather than by layoffs. In 1978 a group of electric furnace steel producers, including most of the small producers in the Brescia area (the "Bresciani"), as well as some of the larger producers, formed an association known as the Ufficio Controllo Raggruppamento Ordini (UCRO). The purpose of the association was to coordinate sales to the EC and administer the minimum pricing requirements of the Davignon plan, and to locate new sales outlets in the EC and other countries.

Japan.—The number of operating blast furnaces declined from 46 out of a total of 66 at the beginning of 1978 to 43 out of 67 at the beginning of 1979; consequently, pig iron production declined 8.5% to 86.6 million tons in 1978. In 1979, four large furnaces were started, and at the same time, four smaller furnaces were shut down, so that pig iron production increased 6.7% to 92.4 million tons in 1979. Raw steel production declined slightly in 1978 to 112.6 million tons but increased to 123.2 million tons in 1979, the highest since 1974. The percentage of electric-furnace steel increased from 19.1% of the total in 1977 to 21.9% in 1978 and 23.6% in 1979. A record 29.1 million tons of steel was made by the electric-furnace process in 1979. The industry was operating at about 70% capacity during 1978-79.

Apparent consumption of steel increased 55.5% to 73.5 million tons (raw steel equivalent) in 1978 and 16.6% to 85.7 million tons in 1979. Capital investment declined by about 25% in 1978 compared with that of 1977, and remained about the same in 1979. About 13% of the total was for antipollution equipment. Exports of steel declined 9.8% in 1978 to 34.8 million tons, but remained about the same in 1979. Exports to the United States decreased by 20.3% to 6.7 million tons in 1978 but then increased 2.4% to 6.8 million tons in 1979. Exports to mainland China increased 24% to 6.2 million tons in 1978 but decreased 20.7% to 4.9 million tons in 1979.

Mexico.—A holding company, Siderúrgica Mexicana (Sidermex) was set up to manage and coordinate the three government-controlled steel companies, Altos Hornos de México S.A. (AHMSA), Fundidora Monterrey S.A., and Siderúrgica Lázaro Cárdenas-Las Truchas S.A. (SICARTSA).

The Mexican Department of Resources and Industrial Development announced a 3-year plan for expansion of the steel industry. The private sector was to add 1.1 million tons to its annual capacity, and Sidermex was to add 2.8 million tons, divided among the three constituent companies as follows: AHMSA, 1.0 million tons; SICARTSA, 1.4 million tons; and Fundidora Monterrey, 0.4 million tons.

Spain.—Funds were made available by the Government for the purchase of shares in Altos Hornos de Mediterráneo (AHM) by the Government holding company, Instituto Nacional de la Industria (INI). United States Steel Corp. withdrew and wrote off its 15% interest in AHM. The company is expected to be 100% nationalized in 4 years. Government funds were also made available for aid to the other two Spanish integrated steel companies.

Sweden.—The steel industry began a recovery at the end of 1978 that continued into 1979. Raw steel production continued a steady increase of about 9% per year from the low tonnage of 1977. The large inventories of finished steel that had previously prevented any increase in steel production were being reduced to normal levels, permitting the price levels to rise.

In 1978, a merger was completed between the three largest nonspecialty steel producers, Norbottens Järnverk AB (NJA), Oxelösunds Järnverk, (formerly a part of Gränges, AB), and the Domnarvet steelworks (formerly of Stora Kopparbergs Bergslags AB) to form the state-owned Svenskt Stål AB.

Mergers also occurred in the specialty steel industry. Uddeholms AB and Gränges Nyby AB merged their stainless steel divisions to form a new company in which Uddeholms would hold 90% of the capital stock and Gränges Nyby the balance. Uddeholms AB also reached an agreement with Sandvik AB to coordinate their strip-rolling facilities and a merger occurred between Fagersta AB and Sandvik AB.

United Kingdom.—The British Steel Corp. (BSC) continued to close plants and facilities and reduce employment and production during 1978-79. Most of the plants scheduled to be shut down were obsolete; at the same time, some of the corporation's most modern facilities came into production. The Redcar works in the Teeside Division began operation of new sinter and pellet plants, coke ovens, and the largest blast furnace in the country, which has a capacity of 10,000 ton per day.

BSC sustained a loss of $603 million in the fiscal year April 1, 1978, through March 31, 1979, compared with a loss of $824 million in the previous fiscal year. Losses for the first half of fiscal year 1979-80 amounted to about $318 million. At the end of 1979, the BSC announced further plant closures and reduction of the steelmaking work force by one-third to 100,000 employees. Steelmaking capacity was to be reduced to 16.5 million tons per year.

U.S.S.R.—Fried. Krupp GmbH, of the Federal Republic of Germany received a contract in March 1979 to build an electric furnace facility at the steel complex being erected in Stary Oskol, near Kursk, U.S.S.R. The raw materials for the plant will consist of 65% direct-reduced iron and 35% scrap. The direct-reduced iron will be produced at the pelletizing and direct-reduction plants being built by two other West German firms, Salzgitter, AG, and Korf Engineering GmbH, which are expected to begin production in 1980. The equipment will consist of four 150-ton Krupp ultrahigh-power electric arc furnaces with water-cooled panels and 90 Mva transformers. The total capacity of 1.6 million tons will consist of 25% ball- and roller-bearing steel, 48% alloy structural steel, 14% unalloyed structural steel, 8% skelp and 4% spring steel. The entire output will be continuously cast on four four-strand casters designed and provided by the U.S.S.R. Production is expected to start in 1982.

Venezuela.—The Plan IV expansion program of the Government-controlled Corporación Venezolana de Guyana-Siderúrgica del Orinco CA (CVG-SIDOR) continued with the starting of a 7.3-million-ton, two-strand pelletizing plant in 1978. The plant is intended to provide raw material for the three series 400 Midrex direct-reduction units that began operation in 1979, as well as three Hojalata y Lámina (HyL) process units under construction. Two electric furnace shops are included in the expansion plans. One shop consists of six 220-ton furnaces with three two-strand slab casters. The other shop consists of four 165-ton furnaces with three six-strand billet casters. Also started in 1979 were a bar mill with 750,000-ton capacity and a wire-rod mill with 450,000-ton capacity.

Enabling legislation was passed in 1978 for the Zulia coal and steel projects to be built near Maracaibo. Financing would be provided partly by the Government and partly from private sources, with the Government holding 51% of equity. The first stage of the steel project was planned to begin operations in 1984 with an initial capacity of 1.1 million tons of finished steel per year, rising to 5 million tons per year by the late 1990's. The Zulia coal mines would supply 4 million tons per year of coal for the steelworks after 1980. The total cost of the two projects was put at about $3,400 million.

TECHNOLOGY

Research has been conducted in recent years on several novel methods of ironmaking or steelmaking. One of these is the ELRED process,[4] developed in Sweden by Stora Kopparbergs Bergslags AB and ASEA AB. The process consists of a two-stage reduction of iron ore by coal to molten pig iron, which can then be refined to steel by conventional methods. In the first stage, a mixture of finely powdered coal and fine iron ore concentrates is reacted in a pressurized fluidized bed to produce a partly metallized product containing excess carbon. The prereduced material, together with fluxes, is finally reduced in a direct-current-arc furnace to produce pig iron. Although the total energy used is about the same as in the blast furnace process, the energy costs are lower because low-cost coal is used instead of metallurgical coke. The process is said to be suitable for use with high-phosphorus ores.

Various processes involving a plasma arc are also being studied. In one version, developed jointly by workers in the German Democratic Republic (GDR) and the U.S.S.R., one or more plasmatrons are introduced through the sidewalls of a furnace similar in shape to a conventional arc furnace, and the plasma, consisting of ionized argon gas at very high temperatures, is used to melt scrap. A hearth electrode completes the circuit. A 30-ton furnace of this type is employed in Freitag, GDR, to produce primarily high alloy steels and other special alloys.[5]

An experimental plasma-arc process is being developed in England, which employs a precessing plasma gun in the roof of the furnace with an anode in the hearth. Iron ore concentrates and powdered coal are injected into the plasma, and slag and metal are produced.[6]

In the Krupp experimental submerged-injection process,[7] coal and oxygen, injected through annular tuyeres into a bath of metal in a refractory-lined vessel, provide the heat required to melt scrap or direct-reduced iron. The melt produced is high in carbon and sulfur, and must be separately refined. The gases produced are high in carbon monoxide and hydrogen, and can be used for heating, power generation, or direct-reduction of iron ore.

New steels have been developed for the automobile industry to permit weight reduction for improved fuel economy. High-strength, low-alloy (HSLA) steels have improved strength over the plain low-carbon steels ordinarily used, but have the disadvantage of reduced formability because of poor stretchability and excessive springback. A group of steels known as dual-phase (or duplex) steels have been developed to eliminate this problem. In these steels, a hard, strong (martensite) phase is dispersed in a matrix of a soft, ductile phase (ferrite) by a special heat treatment. In addition to improved strength, these steels have good formability owing to a high strain-hardening rate and a low yield-to-tensile strength ratio.[8] [9]

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[1] Supervisory physical scientist, Section of Ferrous Metals.

[2] Tons in this chapter refer to short tons of 2,000 pounds.

[3] Federal Register. Title 40—Protection of the Environment; Chapter I—Environmental Protection Agency; Part 60—Standards of Performace for New Stationary Sources, Basic Oxygen Furnaces: Opacity Standards, v. 43, No. 72, Apr. 13, 1978, pp. 15600-15602.

[4] Collin, H. ELRED—A New Process For The Less Expensive Production of Liquid Iron. Iron and Steel Engineer, v. 57, No. 3, March 1980, pp. 43-45.

[5] McCombe, C. Plasma-Arc—A Joint USSR-GDR Development in Electric Steelmaking. Steel Times International, included in Steel Times, v. 206, No. 9, September 1978, pp. 86-87.

[6] Hodson, R. The Plasma Furnace: A Revolution in Steelmaking? SteelWeek, v. 2, No. 14, Apr. 2, 1979.

[7] Radke, D., D. Neuschutz, and J. Hartwig. Melting of Sponge Iron or Scrap in a Steelmaking Vessel by Simultaneously Injecting Fine Coal and Oxygen. Proceedings of the Third International Iron and Steel Congress, Apr. 16-20, 1978, Chicago, Ill., American Society for Metals, Metals Park, Ohio, 1979, pp. 518-524.

[8] Furukawa, T. Dual-Phase Sheet Steels for Automotive Applications. Metal Progress, v. 116, No. 8, December 1979, pp. 36-39.

[9] Koo, J., B. V. N. Rao, and G. Thomas. Designing High Performance Steels with Dual-Phase Structures. Metal Progress, v. 116, No. 8, September 1979, pp. 66-70.

Table 2.—Pig iron produced and shipped in the United States, by State

(Thousand short tons and thousand dollars)

State	Production	Shipped from furnaces		Average value at furnace, dollars per ton
		Quantity	Value	
1978:				
Alabama	3,417	3,486	679,516	194.90
Illinois	6,925	6,917	1,157,091	167.27
Indiana	18,807	18,850	3,533,418	187.45
Michigan	7,324	7,339	1,373,348	187.12
New York	3,459	3,469	691,184	199.24
Ohio	14,311	14,405	2,769,032	192.22
Pennsylvania	18,159	18,795	3,509,896	186.74
California, Colorado, Utah	4,897	4,907	786,015	160.17
Kentucky, Maryland, Texas, West Virginia	10,392	10,373	1,961,971	189.14
Total[1]	87,690	88,543	16,461,466	185.91
1979:				
Alabama	3,675	3,659	738,384	201.82
Illinois	6,162	6,185	1,203,768	194.62
Indiana	18,043	18,064	3,479,697	192.63
Michigan	7,318	7,319	1,397,069	190.88
New York	3,387	3,434	701,673	204.31
Ohio	14,104	14,222	2,834,069	199.27
Pennsylvania	18,409	19,079	3,651,453	191.38
California, Colorado, Utah	5,142	5,150	818,313	158.90
Kentucky, Maryland, Texas, West Virginia	10,735	10,667	2,072,194	194.25
Total[1]	86,975	87,781	16,896,639	192.49

[1] Data may not add to totals shown because of independent rounding.

Table 3.—Foreign iron ore and manganiferous iron ore (excluding agglomerates) consumed in manufacturing pig iron in the United States, by source of ore

(Thousand short tons)

Source	1978[1]	1979[2]
Australia	3[illegible]3	450
Brazil	1,643	603
Canada	1,231	965
Chile	559	128
Liberia	31	1,026
Venezuela	3,575	2,345
Other countries	407	217
Total[3]	7,839	5,785

[1] Excludes 17,526,000 tons used in making agglomerates.
[2] Excludes 15,312,114 tons used in making agglomerates.
[3] Data may not add to totals shown because of independent rounding.

Table 4.—Pig iron shipped from blast furnaces in the United States, by grade[1]

(Thousand short tons and thousand dollars)

Grade	1978			1979		
	Quantity	Value		Quantity	Value	
		Total	Average dollars per ton		Total	Average dollars per ton
Foundry	1,766	788,723	198.77	1,415	282,693	199.72
Basic	83,809	15,103,168	185.43	83,514	16,057,418	192.27
Bessemer	983	199,000	202.37	931	190,210	204.35
Low-phosphorus	126	24,206	191.94	88	17,884	203.84
Malleable	990	188,121	190.00	1,173	226,753	193.30
All other (not ferroalloys)	868	158,246	182.60	660	121,680	184.30
Total[2]	88,543	16,461,466	185.91	87,781	16,896,639	192.49

[1] Includes pig iron transferred directly to steel furnaces at same site.
[2] Data may not add to totals shown because of independent rounding.

Table 5.—Number of blast furnaces in the United States, by State

State	1978			1979		
	In blast[1]	Out of blast	Total	In blast[1]	Out of blast	Total
Alabama	8	2	10	5	5	10
California	4	--	4	4	--	4
Colorado	3	1	4	3	1	4
Illinois	11	8	19	11	1	12
Indiana	23	2	25	22	3	25
Kentucky	2	--	2	2	--	2
Maryland	6	3	9	3	2	5
Michigan	9	--	9	9	--	9
New York	5	4	9	5	4	9
Ohio	25	11	36	23	7	30
Pennsylvania	26	16	42	27	17	44
Texas	2	--	2	2	--	2
Utah	3	--	3	3	--	3
West Virginia	4	--	4	4	--	4
Total	131	47	178	123	40	163

[1] In blast for 180 days or more during the year.

Table 6.—Iron ore and other metalliferous materials, coke, and fluxes consumed in blast furnaces, and pig iron produced in the United States, by State

(Thousand short tons unless otherwise specified)

State	Metalliferous materials consumed in blast furnaces							Net coke	Fluxes	Pig iron produced	Metalliferous materials consumed per ton of pig iron made (short tons)				Coke and fluxes consumed per ton of pig iron (short tons)	
	Iron and manganiferous ores		Agglomerates	Net ores and agglomerates[1]	Net scrap[2]	Miscellaneous[3]	Net total				Net ores and agglomerates[1]	Net scrap[2]	Miscellaneous[3]	Net total	Net coke	Fluxes
	Domestic	Foreign														
1978:																
Alabama	W	1,301	4,452	5,640	43	45	5,728	2,227	316	3,417	1.651	.013	.013	1.676	.652	.092
Illinois	W	78	10,505	10,708	581	372	11,870	4,159	971	6,925	1.546	.084	.054	1.714	.601	.140
Indiana and Michigan	371	498	40,013	40,416	893	1,391	42,700	14,318	1,483	26,131	1.547	.034	.053	1.634	.548	.057
New York	432	150	4,808	5,293	276	95	5,664	2,070	524	3,459	1.530	.080	.027	1.637	.598	.151
Ohio	1,775	862	19,620	21,868	376	965	23,209	8,843	2,957	14,311	1.528	.026	.067	1.622	.618	.207
Pennsylvania	1,707	3,553	23,412	28,156	774	942	29,872	10,965	1,892	18,159	1.551	.043	.052	1.645	.604	.104
California, Colorado, Utah	1,637	403	6,211	8,155	222	99	8,476	2,827	877	4,897	1.665	.045	.020	1.731	.577	.179
Maryland, West Virginia, Kentucky, Texas	171	994	14,973	15,740	379	259	16,377	5,901	923	10,392	1.515	.036	.025	1.576	.568	.089
Total[4]	6,314	7,839	123,994	135,976	3,544	4,168	143,896	51,310	[5]9,943	87,690	1.551	.040	.048	1.641	.585	.113
1979:																
Alabama	W	789	5,209	5,910	--	4	5,914	2,192	302	3,675	1.608	--	.001	1.607	.596	.082
Illinois	W	W	9,493	9,777	481	293	10,551	3,722	821	6,162	1.587	.078	.048	1.712	.604	.133
Indiana and Michigan	481	386	39,262	39,587	1,157	1,337	42,080	14,423	1,351	25,361	1.561	.046	.053	1.659	.569	.053
New York	W	W	5,046	5,148	178	2	5,327	1,906	457	3,387	1.520	.053	.001	1.573	.563	.135
Ohio	1,381	470	19,971	21,395	492	1,028	22,916	8,425	2,784	14,104	1.517	.035	.073	1.625	.597	.197

Pennsylvania	1,301	3,357	25,360	29,488	740	1,014	31,242	9,804	1,475	18,409	1.602	.040	.055	1.697	.533	.080
California, Colorado, Utah	1,420	W	6,679	8,411	192	95	8,699	2,921	784	5,142	1.636	.037	.018	1.692	.568	.152
Maryland, West Virginia, Kentucky, Texas	W	231	16,878	16,729	270	225	17,224	5,518	665	10,735	1.558	.025	.021	1.604	.514	.062
Total[4]	5,047	5,735	127,898	136,445	3,508	3,998	143,953	48,911	[6]8,639	86,975	1.569	.040	.046	1.665	.562	.099

W Withheld to avoid disclosing company proprietary data; included with "Total."

[1] Net ores and agglomerates equal ore plus agglomerates plus flue dust used minus flue dust recovered.

[2] Excludes home scrap produced at blast furnaces.

[3] Does not include recycled material.

[4] Data may not add to totals shown because of independent rounding.

[5] Fluxes consisted of the following: 4,054 limestone, 5,257 dolomite, and 633 other fluxes excluding 4,419 limestone, 6 burnt lime, 4,438 dolomite, and 94 other fluxes used in agglomerating production at or near steel plants and an unknown quantity used in making agglomerates at mines.

[6] Fluxes consisted of the following: 3,706 limestone, 31 burnt lime, 4,380 dolomite, and 521 other fluxes excluding 5,411 limestone, 17 burnt lime, 3,625 dolomite, and 47 other fluxes used in agglomerating production at or near steel plants and an unknown quantity used in making agglomerates at mines.

Table 7.—Steel production in the United States, by type of furnace

(Thousand short tons)

Year	Open hearth	Basic oxygen converter	Electric	Total
1974	35,499	81,552	28,669	145,720
1975	22,161	71,801	22,680	116,642
1976	23,470	79,918	24,612	128,000
1977	20,043	77,408	27,882	125,333
1978	21,310	83,484	32,237	137,031
1979	19,158	83,256	33,927	136,341

Source: American Iron and Steel Institute.

Table 8.—Metalliferous materials consumed in steel furnaces[1] in the United States

(Thousand short tons)

Year	Iron ore[2]		Agglomerates[2]		Pig iron	Ferro-alloys[3]	Iron and steel scrap
	Domestic	Foreign	Domestic	Foreign			
1973	163	1,320	656	243	94,398	1,907	76,352
1974	153	1,126	272	302	90,031	1,950	75,329
1975	92	515	553	189	74,518	1,450	58,071
1976	66	593	584	195	81,926	1,495	63,554
1977	112	372	123	102	77,086	1,519	64,231
1978	110	537	441	79	83,577	1,685	70,375
1979	73	409	704	74	81,948	1,725	71,715

[1] Basic oxygen converter, open-hearth, and electric furnace.

[2] Consumed in integrated steel plants only.

[3] Includes ferromanganese, spiegeleisen, silicomanganese, manganese metal, ferrosilicon, ferrochromium, and ferromolybdenum.

Table 9.—Consumption of pig iron in the United States, by type of furnace or other use

Type of furnace or other use	1977		1978		1979	
	Thousand short tons	Percent of total	Thousand short tons	Percent of total	Thousand short tons	Percent of total
Basic oxygen converter	63,877	77.9	69,028	78.1	68,526	78.4
Open hearth	12,531	15.3	13,444	15.2	12,865	14.7
Electric	998	1.2	1,440	1.6	905	1.0
Cupola	1,241	1.5	1,056	1.2	1,026	1.2
Air and other furnaces[1]	354	.4	398	.4	397	.4
Direct castings[2]	3,007	3.7	3,055	3.5	3,738	4.3
Total[3]	82,008	100.0	88,420	100.0	87,458	100.0

[1] Includes vacuum melting furnaces and miscellaneous melting processes.

[2] Castings made directly from blast furnace hot metal. Includes ingot molds and stools.

[3] Data may not add to totals shown because of independent rounding.

Table 10.—Consumption of pig iron[1] in the United States, by State

(Thousand short tons)

State	1978	1979
Alabama	3,405	3,517
Arkansas	3	3
California	2,020	2,512
Connecticut	11	13
Georgia	5	8
Illinois	6,883	6,191
Indiana	18,909	18,064
Iowa	26	27
Kansas	7	8
Kentucky	1,843	1,704
Maine	(2)	(2)
Maryland	4,355	4,733
Massachusetts	17	19
Michigan	7,577	7,506
Minnesota	38	44
Missouri	12	14
Nevada	(2)	(2)
New Jersey	9	7
New York	3,287	3,253
North Carolina	5	4
Ohio	14,267	14,227
Oklahoma	9	9
Pennsylvania	18,478	18,558
Rhode Island	3	3
Tennessee	28	23
Texas	1,231	1,211
Utah	1,921	1,681
Virginia	105	88
Washington	1	3
West Virginia	2,923	2,944
Wisconsin	90	94
Undistributed[3]	949	990
Total	[4]88,420	87,458

[1] Includes molten pig iron used for ingot molds and direct castings.

[2] Less than 1/2 unit.

[3] Includes Colorado, Florida, New Hampshire, Oregon, and South Carolina in 1978 and 1979.

[4] Data do not add to total shown because of independent rounding.

Table 11.—U.S. exports of major iron and steel products

Products	1978		1979	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Steel mill products:				
Ingots, blooms, billets, slabs, sheet bars	231,095	$47,110	357,965	$93,696
Wire rods	40,772	13,108	28,403	14,180
Structural shapes, 3-inch and over	124,444	52,418	139,054	73,393
Structural shapes, under 3 inches	18,646	11,734	18,234	16,551
Sheet piling	2,840	999	6,823	4,614
Plates	172,064	79,321	207,866	100,986
Rails and track accessories	68,014	24,825	38,148	21,565
Wheels and axles	8,573	10,496	2,496	9,182
Concrete reinforcing bars	111,347	23,333	86,281	28,180
Bars, carbon, hot-rolled	42,346	16,459	68,488	28,872
Bars, alloy, hot-rolled	67,355	40,377	48,382	41,613
Bars, cold-finished	32,170	24,245	29,486	30,561
Hollow drill steel	8,538	5,583	7,874	6,330
Pipe and tubing	561,990	530,326	728,430	791,131
Wire	38,503	41,723	34,827	45,243
Nails, brads, spikes, staples	23,910	23,607	10,320	26,014
Blackplate	79,199	15,872	125,548	35,377
Tinplate and terneplate	374,267	142,389	440,399	204,986
Sheets, hot-rolled	98,679	42,864	100,527	53,582
Sheets, cold-rolled	133,821	62,300	142,507	98,704
Strip, hot-rolled	13,543	10,175	15,607	14,932
Strip, cold-rolled	40,059	50,382	50,146	65,507
Plates, sheets, strip, galvanized, coated or clad	129,503	59,088	130,132	73,296
Total[1]	2,421,678	1,328,734	2,817,943	1,878,437
Other steel products:				
Plates and sheets, fabricated	31,208	39,395	22,362	38,417
Structural shapes, fabricated	119,557	163,021	121,296	195,258
Architectural and ornamental work	5,821	7,965	4,157	8,349
Sashes and frames	11,116	22,002	10,237	25,943
Wire fencing	3,560	6,993	3,172	13,073
Pipe and tube fittings	58,711	182,387	42,058	214,369
Pipe and tubing, coated or lined	20,788	20,853	14,595	20,173
Bolts and nuts	101,814	107,274	95,094	113,687
Forgings	55,121	64,624	56,011	72,397
Cast steel rolls	3,669	5,929	3,432	7,008
Railway track material	5,598	5,623	4,769	5,723
Total[1]	416,958	626,087	377,183	714,398
Iron products:				
Cast iron pipes, tubes, fittings	115,427	124,361	66,367	121,517
Iron castings	320,240	212,323	141,194	102,740
Total[1]	435,667	336,684	207,561	224,257
Grand total[1]	3,274,308	2,291,505	3,402,687	2,817,091

[1] Data may not add to totals shown because of independent rounding.

Table 12.—U.S. imports for consumption of pig iron, by country

Country	1977		1978		1979	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Australia	11,945	$1,998	16,147	$2,352	7,880	$1,000
Belgium-Luxembourg	--	--	6,752	788	--	--
Brazil	122,678	10,955	197,874	20,353	188,925	21,622
Canada	188,860	27,288	240,063	33,472	184,635	28,656
France	6,169	832	29,878	3,631	19,579	2,659
India	--	--	318	55	--	--
Japan	6,097	552	--	--	--	--
Mexico	73	7	--	--	--	--
South Africa, Republic of	--	--	9,258	940	41,776	5,193
Spain	--	--	--	--	28,888	3,286
Sweden	29,732	2,364	144,161	9,396	9,658	834
United Kingdom	7,213	920	10,940	1,247	--	--
Total[1]	372,767	44,916	655,412	72,234	476,342	63,251

[1] Data may not add to totals shown because of independent rounding.

Table 13.—U.S. imports for consumption of major iron and steel products

Products	1978		1979	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Steel mill products:				
Ingots, blooms, billets, slabs, sheet bars	413,898	$97,065	344,690	$91,863
Wire rods	1,326,558	389,141	985,401	379,156
Structural shapes, 3-inch and over	1,798,998	458,756	1,881,959	596,769
Structural shapes, under 3 inches	239,742	57,054	231,608	76,162
Sheet piling	128,008	38,157	102,812	37,822
Plates	2,924,994	718,162	1,819,805	561,640
Rails and track accessories	189,161	51,369	213,677	74,336
Wheels and axles	96,724	47,257	99,550	58,877
Concrete reinforcing bars	109,958	20,807	116,958	33,164
Bars, carbon, hot-rolled	597,826	156,798	452,423	147,958
Bars, alloy, hot-rolled	182,479	94,077	153,894	90,499
Bars, cold-finished	204,459	120,066	170,510	134,527
Hollow drill steel	2,202	1,970	2,023	2,212
Welded pipe and tubing	1,743,347	593,948	1,750,470	724,360
Other pipe tubing	1,302,600	705,529	1,169,584	716,279
Wire	626,926	386,714	479,074	369,848
Wire nails	428,411	188,589	396,849	188,176
Wire fencing, galvanized	19,159	9,768	11,261	7,848
Blackplate	46,016	16,245	82,072	30,850
Tinplate and terneplate	380,552	165,193	262,781	137,252
Sheets, hot-rolled	2,617,000	612,877	2,161,764	608,111
Sheets, cold-rolled	3,236,855	1,022,261	2,412,994	894,821
Sheets, coated (including galvanized)	2,312,997	840,741	2,139,151	892,511
Strip, carbon, hot-rolled	35,657	10,986	27,345	9,661
Strip, carbon, cold-rolled	49,267	41,298	49,581	45,151
Strip, alloy, hot- or cold-rolled (including stainless)	25,043	34,757	21,267	36,682
Plates, sheets, strip, electrolytically coated (other than with tin, lead or zinc)	95,121	36,507	38,588	20,124
Total[1]	21,133,958	6,916,061	17,518,101	6,966,656
Other steel products:				
Plates, sheets, strip, fabricated	10,026	7,468	6,749	7,582
Structural shapes, fabricated	126,196	70,685	154,365	113,101
Pipe fittings	79,267	85,222	81,753	107,851
Rigid conduit	3,324	5,116	3,095	5,035
Bale ties made from strip	28,207	10,720	8,046	3,677
Nails, brads, spikes, staples, tacks, not of wire	17,157	12,569	17,071	15,451
Bolts, nuts, rivets, washers, etc.	509,954	471,161	477,092	496,999
Forgings	22,592	16,977	39,246	27,231
Total[1]	796,723	679,918	787,417	776,928
Iron products:				
Cast iron pipes, tubes, fittings	25,976	21,220	26,852	25,387
Iron castings	69,899	40,473	95,841	53,460
Total[1]	95,875	61,692	122,693	78,847
Grand total[1]	22,026,556	7,657,672	18,428,211	7,822,431

[1] Data may not add to totals shown because of independent rounding.

Table 14.—Pig iron: World production, by country[1]

(Thousand short tons)

Country[2]	1976	1977	1978[p]	1979[e]
North America:				
Canada	10,803	10,649	11,396	[3]12,022
Mexico[4]	3,889	4,762	5,662	5,020
United States	86,848	81,494	87,690	[3]86,975
South America:				
Argentina	[r]1,440	1,521	2,005	[3]2,141
Brazil[4]	[r]9,295	10,735	11,388	[3]12,037
Chile	445	476	594	[3]674
Colombia	315	246	327	270
Peru	246	269	271	290
Venezuela	[r]465	548	760	[3]1,515
Europe:				
Austria	3,658	3,268	3,392	[3]4,081
Belgium	[r]10,896	9,822	11,164	11,900
Bulgaria	1,717	1,779	1,645	1,600
Czechoslovakia	[r]10,444	10,709	10,962	10,600
Finland	1,456	1,944	2,112	[3]2,247
France	20,566	19,714	19,952	[3]21,402
German Democratic Republic[5]	2,787	2,898	2,811	2,750
Germany, Federal Republic of	34,765	31,633	32,916	[3]38,420
Greece	441	485	660	400
Hungary	2,448	2,520	2,570	2,620
Italy	12,821	12,578	12,500	[3]12,486
Luxembourg[5]	4,140	3,933	4,102	[3]4,191
Netherlands	4,702	4,323	5,085	[3]5,306
Norway	723	565	613	[3]721
Poland	8,721	10,490	10,688	10,700
Portugal	379	393	430	400
Romania	8,174	8,580	8,869	9,150
Spain	[r]7,301	7,290	6,893	[3]7,174
Sweden[4]	[r]3,504	2,812	2,735	[3]3,202
Switzerland	25	30	38	--
U.S.S.R	[r]115,086	117,278	120,915	120,000
United Kingdom	[r]15,115	13,380	12,604	14,500
Yugoslavia	[r]2,115	2,138	2,294	[3]2,601
Africa:				
Algeria	413	389	181	181
Egypt[e]	[r]275	275	330	330
Morocco[e]	[r]11	13	13	13
Rhodesia, Southern[e]	[r]1,050	[r]950	950	940
South Africa, Republic of	[r]6,387	6,739	6,514	[3]7,750
Tunisia	119	146	147	150
Asia:				
China:				
Mainland[5]	[r] [e]24,250	27,613	38,349	[3]40,455
Taiwan	116	80	269	[3]358
India	10,776	10,798	10,397	[3]9,663
Iran[e]	[r]690	[r]770	1,000	900
Israel[e]	44	44	44	45
Japan	96,434	94,673	86,629	[3]92,337
Korea, North[e] [6]	3,300	3,900	4,400	4,400
Korea, Republic of	2,136	2,674	3,022	[3]5,581
Thailand	[r]20	22	23	[3]33
Turkey	[r]2,195	1,905	1,852	[3]2,536
Oceania:				
Australia	8,176	7,444	8,088	[3]8,598
New Zealand[e] [4]	[r]55	[r]13	31	30
Total	[r]541,177	537,698	558,352	581,696

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[e]Estimate. [p]Preliminary. [r]Revised.

[1]Table excludes all ferroalloy production except where otherwise noted.

[2]In addition to the countries listed, Vietnam and Zaire have facilities to produce pig iron and may have produced limited quantities during 1975-1978, but output is not reported and available general information is inadequate to permit formulation of reliable estimates of output levels.

[3]Reported figure.

[4]Includes sponge iron output.

[5]May include blast furnace ferroalloys.

[6]Series revised; excludes ferroalloys.

Table 15.—Raw steel:[1] World production, by country

(Thousand short tons)

Country	1976	1977	1978[p]	1979[e]
North and Central America:				
Canada	14,690	15,026	16,423	[2]17,723
Cuba[e]	[r]326	330	330	300
El Salvador	[e]12	15	[e]15	15
Mexico	5,840	6,174	7,468	7,700
United States	128,000	125,333	137,031	[2]136,341
South America:				
Argentina	[r]2,670	2,950	3,064	[2]3,571
Brazil	10,107	12,306	13,345	[2]15,314
Chile	531	604	659	[2]724
Colombia	[r]393	364	431	400
Peru	385	418	416	470
Uruguay	17	19	10	[2]16
Venezuela	1,033	942	948	[2]1,660
Europe:				
Austria	4,935	4,511	4,779	[2]5,420
Belgium	[r]13,388	12,408	13,890	[2]14,817
Bulgaria	2,712	2,854	2,723	[2]2,633
Czechoslovakia	16,196	16,605	16,858	[2]16,314
Denmark	796	756	952	[2]886
Finland	1,812	2,420	2,572	[2]2,716
France	25,597	24,353	25,178	[2]25,754
German Democratic Republic	7,421	7,560	7,690	[2]7,826
Germany, Federal Republic of	46,754	42,974	45,474	[2]50,755
Greece	[r]788	837	1,032	[2]1,102
Hungary	4,026	4,104	4,274	4,300
Ireland	64	52	76	79
Italy	25,845	25,721	26,767	[2]26,731
Luxembourg	5,033	4,772	5,280	[2]5,455
Netherlands	5,717	5,427	6,162	[2]6,400
Norway	[r]1,002	784	895	[2]1,019
Poland	17,240	19,666	21,221	[2]21,191
Portugal	511	591	709	700
Romania	11,831	12,630	12,984	13,780
Spain	[r]12,128	12,238	12,836	[2]13,501
Sweden	5,666	4,374	4,767	[2]5,217
Switzerland	601	723	864	[2]977
U.S.S.R	[r]159,642	161,685	166,929	[2]164,244
United Kingdom	[r]24,553	22,499	22,380	[2]23,596
Yugoslavia	[r]3,031	3,506	3,804	[2]3,899
Africa:				
Algeria	392	441	441	400
Angola	[r]6	6	11	11
Egypt	504	290	[e]600	700
Ghana[e]	17	17	11	6
Kenya[e]	11	11	11	11
Libya[e]	11	11	11	11
Morocco[e]	[r]1	([4])	--	--
Mozambique[e]	[r]22	13	19	22
Nigeria[e]	17	17	17	17
Rhodesia, Southern[e]	[r]1,100	[r]1,000	1,000	1,000
South Africa, Republic of	[r]7,868	8,133	8,598	[2]9,718
Tunisia	113	172	176	176
Uganda	[r]13	17	17	--
Zaire[e]	33	33	NA	NA
Asia:				
Bangladesh	91	128	138	100
Burma	[r]44	44	44	NA
China:				
Mainland	22,000	26,168	35,031	[2]37,952
Taiwan	690	1,008	1,399	[2]1,731
Hong Kong[e]	[r]79	83	83	100
India	10,202	10,933	11,009	10,400
Indonesia	[r]158	160	165	200
Iran[e]	600	600	880	770
Iraq[e]	([4])	([4])	--	--
Israel[e]	[r]88	110	110	110
Japan	118,387	112,882	112,551	[2]129,181
Jordan[e]	110	110	110	110
Korea, North[e]	3,300	3,960	4,400	4,400
Korea, Republic of	2,974	3,017	3,460	[2]5,732
Lebanon[e]	9	8	7	--
Malaysia	[r]209	214	224	[2]257
Philippines	[r]433	401	304	[2]436
Saudi Arabia[e]	[r]5	[r]5	5	5

See footnotes at end of table.

Table 15.—Raw steel:[1] World production, by country —Continued

(Thousand short tons)

Country	1976	1977	1978[p]	1979[e]
Asia: —Continued				
Singapore	224	227	309	[2]327
Syria[e]	[r]88	127	132	100
Thailand	[r]314	331	365	320
Turkey	1,606	1,540	1,664	2,700
Vietnam[e]	[r]220	[r]220	220	165
Oceania:				
Australia	8,569	8,061	8,365	[2]8,957
New Zealand	236	237	243	[2]252
Total	[r]742,061	739,163	783,415	813,927

[e] Estimate. [p] Preliminary. [r] Revised. NA Not available.

[1] Steel formed in first solid state after melting, suitable for further processing or sale; for some countries, includes material reported as "liquid steel," presumably measured in the molten state prior to cooling in any specific form.

[2] Reported figure.

[3] Revised to zero.

Iron and Steel Scrap

By K. W. Palmer[1]

U.S. monthly scrap consumption and production in 1978 followed the pattern of 1976 and 1977 but at a slightly higher level. Thus, while total consumption in 1977 was only 92 million tons,[2] in both 1978 and 1979 consumption was 99 million tons.

Reported consumption of direct-reduced iron (DRI), which fell to 387,000 tons in 1978, increased 79% to 693,000 tons in 1979. Some of the DRI consumed in 1979 was imported.

Table 1.—Salient iron and steel scrap and pig iron statistics in the United States

(Thousand short tons and thousand dollars)

	1978	1979
Stocks Dec. 31:		
Scrap at consumer plants	8,277	8,724
Pig iron at consumer and supplier plants	889	881
Total	9,166	9,605
Consumption:		
Scrap	99,224	98,901
Pig iron	88,420	87,458
Exports:		
Scrap (excludes rerolling material and ships, boats, and other vessels for scrapping)	9,039	11,054
Value	$896,237	$1,142,406
Imports for consumption:		
Scrap (includes tinplate and terneplate scrap)	794	760
Value	$50,220	$70,804

Legislation and Government Programs.—The Institute of Scrap Iron and Steel (ISIS) and the National Association of Recycling Industries (NARI) continued their efforts to obtain lower freight rates on scrap to equalize these rates with those on iron ore or agglomerates. On August 2, 1978, the Court of Appeals for the District of Columbia vacated the Interstate Commerce Commission (ICC) decision of November 1977, which awarded a 5% increase in freight rates on scrap, and substituted a 3% increase retroactive to the date of the original increase. The refunds ordered by the Court of Appeals were under Ex Parte 319 (sub.-No. 1) and the court imposed a deadline of 6 months from October 16, 1978, for the issuance of a new decision. The ICC reopened the record on December 18, 1978, to permit the parties (the carriers, shippers, NARI, and ISIS) to submit new evidence.

The ICC decision announced on April 16, 1979, agreed that scrap iron and iron ore compete and that freight rates have an effect on the movement of recyclables. As the intent of Congress had been to encourage recycling, freight rates on iron ore in the South and West were raised 35%, but this was opposed by four Southern and Western consumers of iron ore. The increase was then reduced to 11% effective September 24, 1979, and only applied to shipments of iron ore in the South and from the South to the West.

AVAILABLE SUPPLY, CONSUMPTION, STOCKS

Available supply was 98 million tons and 99 million tons in 1978 and 1979, respectively, up from 91 million tons in 1977.

Monthly consumption rose from a low of 7.3 million tons in January 1978 to a high of 8.9 million tons in May and slowly declined to 8.3 million tons in December. The level of consumption and production in 1979 commenced at a higher level than that of 1978 but dropped rapidly in November and December, making the yearly totals for 1979 almost identical with those of 1978.

Stocks remained about 8.5 million tons in both years, a little less than those of 1977.

PRICES

Composite prices for No. 1 heavy melting scrap averaged $76.20 in 1978 per long ton as reported by Iron Age. This was above the average of $63.00 in 1977 and below the average of $97.00 in 1979.

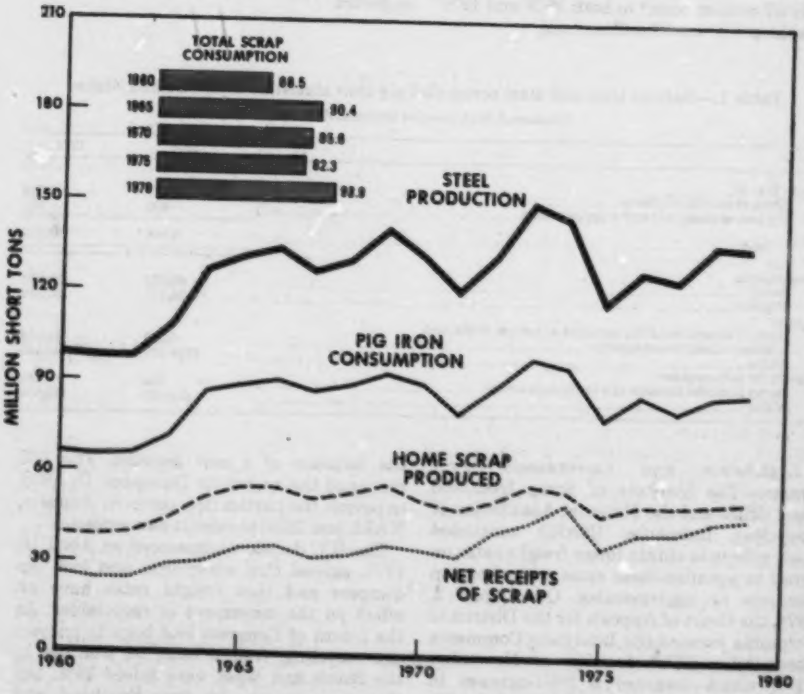

Figure 1.—Steel production (AISI), total iron and steel scrap consumption, pig iron consumption, home scrap production and net scrap receipts.

FOREIGN TRADE

U.S. scrap exports, which had sunk to a 15-year low of 5.9 million tons in 1977, recovered to a more normal 9.0 million tons in 1978. In 1979, exports amounted to 11.1 million tons, a tonnage second to the 1973 record of 11.4 million tons.

Several factors contributed to this large expansion of exports; namely, the expansion of steelmaking in the Republic of Korea, depreciation of the U.S. dollar, recovery of the world ferrous industry, removal of restraints on Japanese electric furnace production, and increased electric furnace capacity in Italy and Spain.

Because of the high scrap prices of early 1979, some U.S. consumers of scrap asked the U.S. Department of Commerce to establish formal monitoring of scrap exports, but this procedure had not been instituted by yearend.

No. 1 heavy melting scrap, which had been the principal grade of scrap exported in 1977, was replaced by shredded or fragmentized scrap in both 1978 and 1979.

Imports of scrap, which had been 614,000 tons in 1977, rose to 717,000 tons and 707,000 tons in 1978 and 1979, respectively. This was above the previous 15-year average of about 300,000 tons.

The Republic of Korea, which had been the principal country of destination for U.S. exports in 1977, was replaced by Japan in both 1978 and 1979.

WORLD REVIEW

Apparent world consumption of ferrous scrap in 1978, as estimated from data available for the principal consuming countries, appeared to increase about 5% over that of 1977, reflecting the increase in world raw steel production. There was a further increase in consumption of about 6% in 1979 over that of 1978, also approximating the increase in world steel production in that year. Total world consumption of scrap, including consumption in foundries, was approximately 500 million tons in 1979 including recirculating scrap.

The United States remained the world's largest exporter of ferrous scrap in 1978 and 1979. France was the second largest exporter, with 4.0 million tons in 1978 and 3.9 million tons in 1979. The Federal Republic of Germany was the third largest exporter, with 2.8 million tons in 1978 and 3.0 million tons in 1979. Under Common Market guidelines, most of the members' exported scrap went to Common Market countries, primarily Italy.

The leading scrap importer was Italy with 6.7 million tons in 1978 and 6.5 million tons in 1979. Italy was followed by Japan with approximately 3.6 million tons of scrap imports in 1978 and 3.7 million tons in 1979. The next largest importer was Spain with 2.1 million tons in 1978 and approximately 2.3 million tons in 1979. It should also be noted that while Taiwan imported only 600,000 tons of scrap in 1978 and 580,000 tons in 1979, the country reported breaking up 265 ships (3.2 million deadweight tons) in 1978 and 351 ships (2.9 million deadweight tons) in 1979.

France reported domestic consumption of purchased scrap as 3.3 million tons in 1978 and 3.4 million tons in 1979, with exports of 4.0 and 3.9 million tons in these respective years. The French steel industry uses a higher ratio of pig iron to scrap than do most Western countries.

The Federal Republic of Germany reported total scrap consumption, including recirculating scrap, of 17.6 million tons in 1978 and 18.4 million in 1979. Exports were 2.8 and 3.0 million tons in 1978 and 1979, respectively.

Italy consumed a high proportion of scrap, because over 53% of raw steel was produced from electric furnaces which use 98% scrap; consumption was 17.8 million tons in 1978 and 17.5 million tons in 1979. These amounts included imports of 6.7 and 6.5 million tons in 1978 and 1979, respectively. Italy's scrap supply problem was aggravated by the fact that over 50% of raw steel was continuously cast, a percentage second only to that of Japan. A shortage of railroad gondolas also made land shipment from the Federal Republic of Germany and France more difficult.

Japan held down total scrap imports to 3.2 million tons in 1978 and 3.3 million tons in 1979 due to a cutback in steel production, especially by electric furnace operators. As a consequence, there was considerable use of iron ore instead of scrap as a coolant in basic oxygen furnaces.

Total United Kingdom consumption of domestic scrap in 1978 was reportedly 16.8 million tons, 10.2 million tons of which was purchased. The United Kingdom exported 1.8 million tons with 0.8 million tons going to other European Economic Community countries. In 1979, the British Scrap Federation reported domestic purchases of 7.5 million tons and exports of 1.4 million tons.

There were some significant shifts in the flow of world ferrous scrap as large units producing gaseously prereduced iron ore DRI came onstream around the world. Thus, production of DRI was increased or commenced in Mexico, Canada, Venezuela, Argentina, Iran, Iraq, Qatar, and Indonesia in both 1978 and 1979. However, because of the low prices of U.S. iron and steel scrap, these vendors of DRI had difficulty competing with scrap prices outside of their own regions.

There were sporadic trial shipments of DRI to the United States, Spain, Italy, India, Japan, the Philippines, and Brazil. The purchasers wanted to learn about transporting, handling, and using DRI and, in some cases, to use it in special heats requiring low residual elements. Another purpose was to have suppliers available in the event of a sizable rise in the price of scrap or a U.S. embargo on scrap exports.

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[1] Physical scientist, Section of Ferrous Metals

[2] All quantities are in short tons unless otherwise noted.

Table 2.—U.S. consumer receipts, production, consumption, shipments and stocks of iron and steel scrap in 1978 and 1979, by grade

(Thousand short tons)

Grade of scrap	Receipts of scrap: From brokers, dealers, and other outside sources 1978	1979	From other own-company plants 1978	1979	Production of home scrap: Recirculating scrap resulting from current operations 1978	1979	Obsolete scrap (includes ingot molds, stools, and scrap from old equipment, obsolete buildings, etc.) 1978	1979	Consumption of both purchased and home scrap (includes recirculating scrap) 1978	1979	Shipments of scrap 1978	1979	Ending stocks Dec. 31 1978	1979
MANUFACTURERS OF PIG IRON AND RAW STEEL AND CASTINGS[1]														
Carbon steel:														
Low-phosphorus plate and punchings	488	475	14	16	43	48	9	10	537	537	52	61	76	53
Cut structural and plate	378	344	153	232	267	440	(2)	--	835	1,027	--	2	35	32
No. 1 heavy melting steel	6,479	8,066	3,075	3,120	18,494	17,855	83	167	26,202	26,481	2,495	2,801	2,113	2,206
No. 2 heavy melting steel	2,524	2,450	99	105	1,317	1,461	4	6	3,858	3,935	106	99	430	429
No. 1 and electric furnace bundles	7,202	6,799	506	651	3,095	2,941	5	5	11,159	10,364	79	160	1,333	1,175
No. 2 and all other bundles	1,920	2,140	44	52	70	68	6	--	1,998	2,186	44	49	265	412
Electric furnace 1 foot and under (not bundles)	40	50	3	(2)	4	11	(2)	(2)	46	60	--	--	6	6
Railroad rails	97	50	1	1	(2)	--	--	--	94	55	(2)	--	7	2
Turnings and borings	1,570	1,446	73	98	361	419	1	1	1,871	1,868	120	101	113	125
Slag scrap (Fe content 70%)	1,398	1,588	25	90	2,787	3,119	61	(2)	4,156	4,725	58	95	195	170
Shredded or fragmentized	1,988	2,425	440	467	29	34	(2)	--	2,496	2,868	1	1	164	220
No. 1 busheling	1,444	1,487	35	22	37	51	--	(2)	1,549	1,579	7	25	145	111
All other carbon steel scrap	2,050	1,956	246	278	11,064	11,243	516	518	13,137	12,971	757	862	730	758
Stainless steel scrap	375	401	39	49	662	745	6	(2)	1,022	1,139	55	62	96	89
Alloy steel (except stainless)	220	247	239	261	1,631	1,544	6	15	1,964	1,945	154	150	258	233
Ingot mold and stool scrap	452	436	673	690	980	1,242	2,040	2,056	3,383	3,280	846	898	575	825
Machinery and cupola cast iron	16	19	2	2	61	16	--	8	18	26	60	22	20	16

See footnotes at end of table.

Table 2.—U.S. consumer receipts, production, consumption, shipments and stocks of iron and steel scrap in 1978 and 1979, by grade—Continued

(Thousand short tons)

Grade of scrap	Receipts of scrap				Production of home scrap				Consumption of both purchased and home scrap (includes recirculating scrap)		Shipments of scrap		Ending stocks Dec. 31	
	From brokers, dealers, and other outside sources		From other own-company plants		Recirculating scrap resulting from current operations		Obsolete scrap (includes ingot molds, stools, and scrap from old equipment, obsolete buildings, etc.)							
	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979
MANUFACTURERS OF PIG IRON AND RAW STEEL AND CASTINGS[1]—Continued														
Cast iron borings	301	349	121	67	288	191	84	43	668	591	94	63	119	126
Motor blocks	9	5	--	--	--	(2)	--	--	11	5	(2)	--	(2)	(2)
Other iron scrap	309	452	170	156	689	862	19	17	818	961	331	345	177	362
Other mixed scrap	246	257	97	137	205	237	(2)	(2)	475	585	68	50	73	78
Total scrap[3]	29,504	31,471	6,147	6,484	42,081	42,528	2,839	2,848	76,294	77,190	5,357	5,846	6,930	7,427
MANUFACTURERS OF STEEL CASTINGS[4]														
Carbon steel:														
Low-phosphorus plate and punchings	618	709	5	11	213	236	(2)	(2)	831	947	2	2	65	76
Cut structural and plate	184	221	18	16	31	27	--	--	235	255	2	1	18	28
No. 1 heavy melting steel	136	172	2	5	67	85	3	1	214	254	1	6	19	21
No. 2 heavy melting steel	61	102	(2)	--	19	21	--	--	78	110	--	--	5	15
No. 1 and electric furnace bundles	50	42	--	--	2	2	--	--	52	40	--	--	2	4
No. 2 and all other bundles	4	4	--	--	--	--	--	--	4	4	--	--	2	1
Electric furnace 1 foot and under (not bundles)	70	70	1	1	19	17	--	--	87	85	1	1	5	5
Railroad rails	1	1	(2)	--	--	--	--	--	1	--	--	--	(2)	(2)
Turnings and borings	62	61	7	6	23	23	(2)	--	82	81	9	8	5	3
Slag scrap (Fe content 70%)	(2)	--	--	--	4	2	--	--	4	2	(2)	(2)	(2)	(2)

Shredded or fragmentized	70	51	21	20	--	--	--	--	92	75	--	--	6	3
No. 1 bundling	48	28	12	13	12	(*)	--	--	65	40	--	--	8	4
All other carbon steel scrap	503	471	40	32	317	329	4	1	968	849	10	10	51	38
Stainless steel scrap	19	21	1	1	25	28	(*)	(*)	49	47	5	6	5	5
Alloy steel (except stainless)	56	66	10	11	133	123	(*)	(*)	147	195	1	1	25	29
Ingot mold and stool scrap	5	5	--	(*)	(*)	1	--	--	5	4	(*)	(*)	1	1
Machinery and cupola cast iron	10	6	(*)	1	9	6	--	--	20	11	--	(*)	2	2
Cast iron borings	52	68	(*)	(*)	81	81	--	--	81	88	1	1	5	6
Motor blocks	1	1	--	--	--	--	--	--	1	1	--	--	(*)	(*)
Other iron scrap	34	32	(*)	4	84	86	(*)	(*)	116	120	8	5	15	12
Other mixed scrap	1	(*)	--	--	5	5	--	--	6	5	(*)	--	(*)	(*)
Total scrap[2]	1,985	2,128	129	121	984	1,086	7	3	3,534	3,218	40	42	241	253
IRON FOUNDRIES AND MISCELLANEOUS USERS														
Carbon steel:														
Low-phosphorus plate and punchings	823	852	161	98	93	101	(*)	(*)	1,096	1,045	7	13	50	47
Cut structural and plate	1,528	1,520	100	87	165	176	1	1	1,739	1,773	4	5	105	106
No. 1 heavy melting steel	329	217	113	78	60	65	1	--	443	320	52	41	62	55
No. 2 heavy melting steel	56	52	5	4	25	31	1	(*)	86	89	1	2	5	3
No. 1 and electric furnace bundles	188	177	191	163	74	60	(*)	(*)	451	416	1	--	15	15
No. 2 and all other bundles	554	536	136	4	--	--	--	--	706	531	1	--	37	33
Electric furnace 1 foot and under (not bundles)	73	178	(*)	71	8	3	(*)	--	81	254	--	--	7	10
Railroad rails	109	185	(*)	(*)	3	(*)	--	--	109	131	(*)	(*)	14	12
Turnings and borings	725	588	173	94	16	20	(*)	(*)	895	622	20	18	82	100
Slag scrap (Fe content 70%)	70	77	1	--	1	14	--	--	79	87	1	7	24	15
Shredded or fragmentized	848	838	130	20	--	7	--	--	1,005	881	6	1	22	48
No. 1 bundling	292	329	113	29	13	14	--	--	404	388	--	18	17	10
All other carbon steel scrap	965	943	770	596	150	157	(*)	(*)	1,904	1,724	10	6	127	101
Stainless steel scrap	1	4	(*)	(*)	7	19	(*)	(*)	8	20	1	2	2	2
Alloy steel (except stainless)	59	71	2	(*)	5	6	1	2	65	74	5	3	8	9
Ingot mold and stool scrap	136	161	4	6	100	74	6	5	237	218	7	8	47	53
Machinery and cupola cast iron	863	896	89	89	772	717	6	4	1,717	1,690	23	8	85	90
Cast iron borings	581	668	759	564	396	411	2	1	1,850	1,601	57	53	78	72
Motor blocks	685	666	69	16	452	375	--	(*)	1,142	1,014	2	4	67	56
Other iron scrap	363	998	125	101	3,288	3,141	29	14	4,290	4,130	121	139	194	149
Other mixed scrap	396	455	567	658	375	369	6	8	1,648	1,482	7	12	44	54
Total scrap[2]	10,225	10,302	3,006	2,665	6,106	5,768	55	36	19,896	18,490	324	341	1,106	1,043

See footnotes at end of table.

Table 2.—U.S. consumer receipts, production, consumption, shipments and stocks of iron and steel scrap in 1978 and 1979, by grade—Continued

(Thousand short tons)

Grade of scrap	Receipts of scrap: From brokers, dealers, and other outside sources 1978	Receipts of scrap: From brokers, dealers, and other outside sources 1979	Receipts of scrap: From other own-company plants 1978	Receipts of scrap: From other own-company plants 1979	Production of home scrap: Recirculating scrap resulting from current operations 1978	Production of home scrap: Recirculating scrap resulting from current operations 1979	Production of home scrap: Obsolete scrap (includes ingot molds, stools, and scrap from old equipment, obsolete buildings, etc.) 1978	Production of home scrap: Obsolete scrap (includes ingot molds, stools, and scrap from old equipment, obsolete buildings, etc.) 1979	Consumption of both purchased and home scrap (includes recirculating scrap) 1978	Consumption of both purchased and home scrap (includes recirculating scrap) 1979	Shipments of scrap 1978	Shipments of scrap 1979	Ending stocks Dec. 31 1978	Ending stocks Dec. 31 1979
TOTAL—ALL TYPES OF MANUFACTURERS														
Carbon steel:														
Low-phosphorus plate and punchings	1,829	2,087	180	120	349	395	10	11	2,463	2,529	60	76	191	176
Cut structural and plate	2,070	2,085	272	235	463	643	1	1	2,807	3,055	6	8	158	168
No. 1 heavy melting steel	6,934	8,477	3,190	3,208	18,620	18,005	87	168	26,859	27,055	2,548	2,848	2,195	2,282
No. 2 heavy melting steel	2,641	2,612	108	110	1,361	1,513	4	6	4,022	4,134	107	101	439	447
No. 1 and electric furnace bundles	7,441	7,018	787	814	3,172	3,012	5	6	11,082	10,820	80	160	1,350	1,194
No. 2 and all other bundles	2,478	2,079	180	56	70	68	6	--	2,710	2,721	45	49	304	446
Electric furnace 1 foot and under (not bundles)	184	298	4	72	32	32	(3)	(3)	215	399	1	1	18	21
Railroad rails	297	185	1	1	3	(3)	--	--	204	186	1	(3)	22	14
Turnings and borings	2,356	2,045	258	198	402	462	1	1	2,848	2,580	149	128	200	228
Slag scrap (Fe content 70%)	1,489	1,665	27	90	2,791	3,135	61	(3)	4,238	4,815	89	102	219	185
Shredded or fragmentized	2,906	3,305	591	507	29	41	(3)	--	3,503	3,824	7	2	293	271
No. 1 busheling	1,774	1,844	159	74	61	65	--	(3)	2,021	2,007	7	44	169	125
All other carbon steel scrap	3,587	3,371	1,056	907	11,532	11,740	520	520	15,908	15,544	777	878	909	897
Stainless steel scrap	356	425	40	50	685	791	6	1	1,073	1,205	61	69	102	95
Alloy steel (except stainless)	235	284	251	273	1,768	1,672	8	17	2,176	2,214	160	154	294	271
Ingot mold and stool scrap	593	601	678	687	1,080	1,316	2,045	2,061	3,625	3,502	853	907	623	578

Machinery and cupola cast iron	889	921	92	92	842	729	6	12	1,756	1,727	83	30	107	108
Cast iron borings	934	1,085	861	632	712	634	86	44	2,439	2,250	151	116	202	205
Motor blocks	695	671	69	16	453	375	--	(2)	1,154	1,020	2	4	68	59
Other iron scrap	1,206	1,482	295	261	4,161	4,089	49	31	5,323	5,211	460	489	387	523
Other mixed scrap	643	712	964	795	585	611	6	8	2,128	2,072	75	62	117	132
Total scrap[3]	41,714	43,901	10,074	9,290	49,181	49,231	2,901	2,888	99,224	98,901	5,720	6,228	8,277	8,724

[1] Includes only those castings made by companies producing raw steel.
[2] Less than 1/2 unit.
[3] Data may not add to totals shown because of independent rounding.
[4] Excludes companies that produce both raw steel and steel castings.

Table 3.—U.S. consumer receipts, production, consumption, shipments, and stocks of pig iron and direct-reduced iron in 1978 and 1979

(Thousand short tons)

	Receipts	Production	Consumption	Shipments	Stocks Dec. 31
1978:					
MANUFACTURERS OF PIG IRON AND RAW STEEL AND CASTINGS					
Pig iron	5,720	87,690	85,701	8,070	764
MANUFACTURERS OF STEEL CASTINGS					
Pig iron	45	--	46	([1])	6
IRON FOUNDRIES AND MISCELLANEOUS USERS					
Pig iron	2,646	--	2,672	7	120
TOTAL—ALL TYPES OF MANUFACTURERS[2]					
Pig iron	8,411	87,690	88,420	8,078	889
Direct-reduced or prereduced iron	399	W	384	W	15
1979:					
MANUFACTURERS OF PIG IRON AND RAW STEEL AND CASTINGS					
Pig iron	3,483	86,986	84,742	6,691	762
MANUFACTURERS OF STEEL CASTINGS					
Pig iron	48	--	47	([1])	6
IRON FOUNDRIES AND MISCELLANEOUS USERS					
Pig iron	2,657	--	2,668	11	113
TOTAL—ALL TYPES OF MANUFACTURERS[2]					
Pig iron	6,188	86,986	87,458	6,703	881
Direct-reduced or prereduced iron	622	W	693	W	43

W Withheld to avoid disclosing company proprietary data.

[1] Less than 1/2 unit.

[2] Data may not add to totals shown because of independent rounding.

Table 4.—Consumption of iron and steel scrap and pig iron in the United States, by type of consumer and type of furnace, or other use

(Thousand short tons)

Type of furnace or other use	Manufacturers of pig iron and raw steel and castings		Manufacturers of steel castings		Iron foundries and miscellaneous users		Total all types[1]	
	Scrap	Pig iron	Scrap	Pig iron	Scrap	Pig iron	Scrap	Pig iron
1978:								
Blast furnace[2]	4,185	--	--	--	--	--	4,185	--
Basic oxygen process[3]	26,006	69,028	--	--	--	--	26,006	69,028
Open-hearth furnace	11,675	13,437	94	7	--	--	11,768	13,444
Electric furnace	32,694	1,112	2,782	34	5,813	294	41,289	1,440
Cupola furnace	394	189	129	1	13,553	867	14,077	1,056
Other (including air furnace)[4]	1,340	355	30	4	530	38	1,899	398
Direct castings[5]	--	1,581	--	--	--	1,474	--	3,055
Total[1]	76,294	85,701	3,034	46	19,896	2,672	99,224	88,420
1979:								
Blast furnace[2]	4,117	--	--	--	--	--	4,117	--
Basic oxygen process[3]	26,496	68,526	--	--	--	--	26,496	68,526
Open-hearth furnace	10,406	12,860	72	5	--	--	10,478	12,865
Electric furnace	34,813	559	3,001	38	5,740	308	43,555	905
Cupola furnace	281	201	117	1	12,376	824	12,774	1,026
Other (including air furnace)[4]	1,077	357	22	4	383	36	1,482	397
Direct castings[5]	--	2,239	--	--	--	1,499	--	3,738
Total[1]	77,190	84,742	3,213	47	18,498	2,668	98,901	87,458

[1] Data may not add to totals shown because of independent rounding.

[2] Includes consumption in all blast furnaces producing pig iron.

[3] Includes scrap and pig iron processed in metallurgical blast cupolas and used in oxygen converters.

[4] Includes vacuum melting furnaces and miscellaneous uses.

[5] Includes ingot molds and stools.

Table 5.—Proportion of iron and steel scrap and pig iron used in furnaces in 1978 and 1979 in the United States

(Percent)

Type of furnace	1978		1979	
	Scrap	Pig iron	Scrap	Pig iron
Basic oxygen process	27.4	72.6	27.9	72.1
Open-hearth furnace	46.7	53.3	44.9	55.1
Electric furnace	96.6	3.4	98.0	2.0
Cupola furnace	93.0	7.0	92.6	7.4
Other (including air furnace)	82.7	17.3	78.9	21.1

Table 6.—Iron and steel scrap supply[1] available for consumption, by State and region

(Thousand short tons)

State and region	Receipts of scrap				Production of home scrap									
	From brokers, dealers, and other outside sources		From other company-owned plants		Recirculating scrap resulting from current operations		Obsolete scrap (includes ingot molds, stools, and scrap from old equipment, buildings, etc.)		Total new supply[2]		Shipments of scrap[3]		New supply available for consumption	
	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979
New England and Middle Atlantic:														
Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, Vermont	1,805	1,770	248	239	1,713	1,706	28	36	3,795	3,752	384	570	3,411	3,182
Pennsylvania	5,777	5,764	2,381	2,618	10,735	11,060	739	836	19,633	20,278	2,161	2,166	17,471	18,112
Total[2]	7,582	7,534	2,629	2,857	12,448	12,767	767	872	23,428	24,030	2,545	2,736	20,883	21,294
North Central:														
Illinois	5,277	5,236	894	669	4,115	4,190	723	531	11,008	10,625	349	378	10,658	10,247
Indiana	2,803	2,785	162	183	8,532	8,474	500	524	11,996	11,966	745	784	11,251	11,182
Michigan, Iowa, Minnesota, Nebraska, Kansas, Missouri	6,714	7,305	3,294	2,436	4,498	4,178	144	213	14,645	14,132	237	168	14,408	13,964
Ohio	5,425	5,344	1,825	1,848	7,955	7,916	283	306	15,487	15,413	912	997	14,576	14,416
Wisconsin	785	859	41	13	620	654	(4)	(4)	1,447	1,526	24	32	1,423	1,495
Total[2]	21,004	21,529	6,215	5,149	25,715	25,412	1,650	1,574	54,583	53,663	2,268	2,359	52,315	51,304

South Atlantic:														
Delaware, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia	3,906	4,718	324	248	3,439	3,695	276	242	7,946	8,902	103	236	7,842	8,667
South Central:														
Alabama, Arkansas, Kentucky, Louisiana, Mississippi, Oklahoma, Tennessee, Texas	6,045	6,783	607	760	4,805	4,602	99	97	11,577	12,242	657	695	10,900	11,546
Mountain and Pacific:														
Arizona, California, Colorado, Hawaii, Montana, Nevada, Oregon, Utah, Washington	3,177	3,338	298	276	2,774	2,856	109	103	6,358	6,573	148	202	6,210	6,370
U.S. total[2]	41,714	43,892	10,074	9,290	49,181	49,331	2,901	2,888	103,892	105,410	5,720	6,228	98,150	99,182

[1] New supply available for consumption is a net figure computed by adding production to receipts and deducting scrap shipped during the year. The plus or minus difference in stock levels at the beginning and end of year is not taken into consideration.

[2] Data may not add to totals shown because of independent rounding.

[3] Includes scrap shipped, transferred, or otherwise disposed of during the year.

[4] Less than 1/2 unit.

Table 7.—Consumption of iron and steel scrap and pig iron[1] by State and region, by type of manufacturer

(Thousand short tons)

State and region	Pig iron and raw steel and castings		Steel castings		Iron foundries and miscellaneous users		Total[2]	
	Scrap	Pig iron	Scrap	Pig iron	Scrap	Pig iron	Scrap	Pig iron
1978:								
New England and Middle Atlantic:								
Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, Vermont	2,225	3,033	147	6	1,201	291	3,573	3,330
Pennsylvania	16,281	17,890	352	15	877	573	17,510	18,478
Total[2]	18,506	20,293	498	20	2,078	864	21,083	21,808
North Central:								
Illinois	8,574	6,572	435	1	1,679	310	10,688	6,883
Indiana	10,291	18,813	243	1	869	95	11,402	18,909
Michigan, Iowa, Minnesota, Nebraska, Kansas, Missouri	7,641	7,155	447	1	6,541	504	14,628	7,661
Ohio	11,164	13,734	295	10	3,293	523	14,751	14,267
Wisconsin	--	--	312	1	1,122	89	1,434	90
Total[2]	37,669	46,274	1,732	14	13,504	1,521	52,903	47,809
South Atlantic:								
Delaware, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia	6,791	W	63	2	924	133	7,778	135
South Central:								
Alabama, Arkansas, Kentucky, Louisiana, Mississippi, Oklahoma, Tennessee, Texas	8,000	[3]13,645	414	4	2,762	135	11,176	13,786
Mountain and Pacific:								
Arizona, California, Colorado, Montana, Nevada, Oregon, Utah, Washington	5,327	4,858	327	6	628	19	6,283	4,883
U.S. total[2]	76,294	85,701	3,034	46	19,896	2,672	99,224	88,420
1979:								
New England and Middle Atlantic:								
Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, Vermont	2,124	3,054	159	1,215	1,212	237	3,495	3,297
Pennsylvania	16,428	17,945	395	16	943	597	17,766	18,558
Total[2]	18,552	20,999	554	1,231	2,155	834	21,261	21,855
North Central:								
Illinois	8,285	5,839	459	(4)	1,588	351	10,331	6,191
Indiana	9,774	17,974	231	1	808	88	10,813	18,064
Michigan, Iowa, Minnesota, Nebraska, Kansas, Missouri	7,937	7,141	451	1	5,686	457	14,074	7,599
Ohio	11,256	13,654	311	11	2,978	563	14,546	14,227
Wisconsin	--	--	327	1	1,181	93	1,507	94
Total[2]	37,251	44,608	1,778	15	12,240	1,552	51,270	46,175
South Atlantic:								
Delaware, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia	7,771	W	67	2	837	119	8,675	121
South Central:								
Alabama, Arkansas, Kentucky, Louisiana, Mississippi, Oklahoma, Tennessee, Texas	8,155	[3]13,990	412	4	2,646	138	11,213	14,131
Mountain and Pacific:								
Arizona, California, Colorado, Hawaii, Montana, Nevada, Oregon, Utah, Washington	5,447	5,145	401	6	620	25	6,482	5,176
U.S. total[2]	77,190	84,742	3,213	47	18,498	2,668	98,901	87,456

W Withheld to avoid disclosing company proprietary data. Included in "South Central" region.

[1] Includes molten pig iron used for ingot molds and direct castings.

[2] Data may not add to totals shown because of independent rounding.

[3] Includes South Atlantic Region.

[4] Less than 1/2 unit.

Table 8.—Consumer stocks of iron and steel scrap, by grade, and pig iron, Dec. 31, 1978 and 1979, by State and region

(Thousand short tons)

State and region	Carbon steel (excludes rerolling rails)		Stainless steel		Alloy steel (excludes stainless)		Cast iron (includes borings)		Other grades of scrap		Total scrap stocks[1]		Pig iron stocks	
	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979
New England and Middle Atlantic:														
Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, Vermont	445	267	18	17	25	25	217	97	4	4	708	409	195	143
Pennsylvania	1,185	1,353	44	30	119	111	339	505	3	50	1,690	2,049	168	213
Total[1]	1,630	1,620	62	47	144	136	556	601	6	53	2,398	2,458	364	356
North Central:														
Illinois	878	787	8	(²)	8	22	97	97	1	1	988	907	32	16
Indiana	700	771	7	7	26	20	102	392	46	11	881	1,201	17	26
Michigan, Iowa, Minnesota, Nebraska, Kansas, Missouri	663	530	7	5	2	1	140	140	13	18	826	694	35	24
Ohio	828	665	12	21	51	48	158	205	3	6	1,052	946	273	196
Wisconsin	17	21	1	1	(²)	(²)	11	13	(²)	(²)	29	35	12	8
Total[1]	3,087	2,773	30	34	87	92	509	847	64	36	3,777	3,783	369	269
South Atlantic:														
Delaware, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia	500	653	7	12	10	7	43	73	W	W	560	745	19	41
South Central:														
Alabama, Arkansas, Kentucky, Louisiana, Mississippi Oklahoma, Tennessee, Texas	694	1,029	1	1	40	23	126	150	[3]27	[3]27	888	1,230	94	184
Mountain and Pacific:														
Arizona, California, Colorado, Montana, Nevada, Oregon, Utah, Washington	467	379	1	1	13	13	153	101	18	15	653	509	43	30
U.S. total[1]	6,387	6,453	102	95	294	271	1,387	1,772	117	132	8,277	8,724	889	881

W Withheld to avoid disclosing company proprietary data. Included in South Central Region.

[1] Data may not add to totals shown because of independent rounding.

[2] Less than 1/2 unit.

[3] Includes South Atlantic Region.

Table 9.—Average monthly price and composite price for No. 1 heavy melting scrap

(Per long ton)

Month	1978	1979	1978	1979	1978	1979	1978	1979
	Chicago		Pittsburgh		Philadelphia		Composite price[1]	
January	$71.50	98.30	$71.50	93.30	$68.70	101.10	$70.56	97.56
February	71.50	109.75	72.00	111.75	72.75	110.75	72.08	110.75
March	72.25	121.25	74.50	127.75	76.00	110.25	74.25	119.75
April	76.00	99.30	77.50	102.90	74.75	97.70	76.08	99.96
May	71.50	99.75	73.10	102.75	71.10	90.75	71.90	97.75
June	75.30	104.00	74.70	105.50	74.30	93.08	74.76	100.83
July	77.75	96.90	77.50	99.90	78.00	91.50	77.75	96.10
August	74.00	88.25	77.00	93.50	78.00	89.25	76.33	90.33
September	69.50	86.50	73.75	89.25	75.50	88.50	72.91	88.08
October	72.50	87.30	75.70	87.30	76.30	87.30	74.83	87.30
November	83.00	94.50	83.25	94.50	84.00	88.50	83.41	92.50
December[2]	91.25	93.25	87.00	95.25	91.50	91.75	89.91	93.41
Average 1979[e]	--	98.25	--	100.30	--	95.03	--	97.86
Average 1978	75.50	--	76.45	--	76.74	--	76.23	--
Average 1977[r]	60.70	--	65.64	--	63.14	--	63.15	--

[e] Estimate. [r] Revised.

[1] Composite price, Chicago, Pittsburgh, and Philadelphia.

[2] Estimated in 1979.

Source: Iron Age, Jan. 7, 1980.

Table 10.—U.S. exports and imports for consumption of iron and steel scrap, by class

(Thousand short tons and thousand dollars)

Class	1975		1976		1977		1978		1979	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Exports:										
No. 1 heavy melting scrap	2,766	233,784	2,064	150,327	1,750	107,089	2,362	175,933	2,697	269,845
No. 2 heavy melting scrap	1,102	85,508	705	46,047	594	33,870	837	56,433	1,117	104,017
No. 1 bundles	120	9,574	95	7,726	103	2,442	148	11,231	145	14,455
No. 2 bundles	1,159	71,908	845	48,144	336	14,429	326	17,065	652	46,889
Stainless steel scrap	66	27,463	112	52,516	75	37,154	115	44,439	112	66,118
Shredded steel scrap	2,406	206,691	2,179	164,922	1,606	97,602	2,684	198,377	2,980	308,283
Borings, shovelings, turnings	597	29,721	644	32,339	476	17,916	750	33,163	889	59,467
Other steel scrap[1]	726	63,565	750	65,809	601	49,960	1,382	128,350	1,828	211,352
Iron scrap	500	34,767	474	33,996	314	20,579	434	33,258	632	61,879
Total[2]	9,442	762,976	7,877	601,826	5,854	381,041	9,039	698,237	11,054	1,142,406
Ships, boats, other vessels (for scrapping)	40	1,742	50	2,280	35	2,613	2	232	73	5,436
Rerolling material	160	16,266	241	32,652	321	31,691	50	5,528	70	10,222
Total[2]	9,642	780,984	8,168	636,753	6,211	415,345	9,090	703,996	11,197	1,158,064
Imports:										
Iron and steel scrap	305	25,250	507	35,120	614	40,501	794	50,220	760	70,804

[1] Includes terneplate and tinplate.

[2] Data may not add to totals shown because of independent rounding.

Table 11.—U.S. exports of iron and steel scrap, by country of destination

(Thousand short tons and thousand dollars)

Country	1975		1976		1977		1978		1979	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Canada	873	44,676	889	48,140	522	23,847	795	41,698	861	60,275
Greece	161	12,964	222	17,475	300	17,192	340	25,079	500	52,395
Italy	613	57,548	634	57,489	206	18,441	657	54,522	1,186	124,361
Japan	2,405	198,884	1,256	93,115	1,036	61,927	3,190	238,979	2,922	305,509
Korea, Republic of	762	61,842	911	61,561	1,441	88,668	1,508	117,742	1,418	152,483
Mexico	1,269	103,208	571	44,541	322	22,555	450	35,808	814	85,098
Spain	1,709	131,600	1,862	136,098	784	46,909	744	58,038	1,400	127,592
Taiwan	264	24,168	249	22,063	435	35,647	394	41,126	634	70,004
Turkey	89	6,645	159	13,461	310	20,044	258	19,583	242	23,482
Other	1,297	121,441	1,124	107,888	496	45,811	708	70,662	1,077	141,207
Total	9,442	762,976	7,877	601,826	5,854	381,041	9,039	698,237	11,054	1,142,406

Table 12.—U.S. exports of rerolling material (scrap), by country of destination

(Thousand short tons and thousand dollars)

Country	1975		1976		1977		1978		1979	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Korea, Republic of	29	3,189	44	11,098	99	9,371	--	--	2	172
Mexico	40	4,623	24	2,464	21	2,061	38	4,176	57	8,614
Pakistan	4	402	3	278	18	742	7	470	--	--
Thailand	13	1,518	76	8,426	133	14,078	--	--	--	--
Turkey	(1)	61	4	541	16	1,709	--	--	--	--
Other	74	6,473	90	9,845	34	3,730	6	882	11	1,436
Total	160	16,266	241	32,652	321	31,691	[2]50	5,528	70	10,222

[1] Less than 1/2 unit.

[2] Data do not add to total shown because of independent rounding.

Table 13.—U.S. imports for consumption of iron and steel scrap,[1] by country

Country	1978		1979	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Austria	35,867	$611	100	$830
Belgium-Luxembourg	7,368	266	43,854	287
Canada	609,946	42,771	661,657	59,304
Germany, Federal Republic of	13,068	565	758	572
Japan	17,364	1,006	6,750	4,649
Mexico	17,880	1,032	20,960	1,440
Netherlands	50,141	1,746	8,737	855
Panama	21,720	277	2	1
Sweden	1,900	360	5,153	681
United Kingdom	6,849	836	8,233	969
Other	11,861	750	4,062	1,216
Total	793,954	50,220	760,266	70,804

[1] Includes tinplate.

Kyanite and Related Materials

By Michael J. Potter[1]

Kyanite, andalusite, and sillimanite are anhydrous aluminum silicate minerals that are alike in both composition and use patterns and have the same chemical formula, $Al_2O_3 \cdot SiO_2$. Related materials include synthetic mullite, dumortierite, and topaz, also classified as aluminum silicates, although the last two additionally contain substantial proportions of boron and fluorine, respectively. All of these kyanite-group substances can serve as raw materials for manufacturing special high-performance, high-alumina refractories, but there has been no record in recent years of significant utilization of either dumortierite or topaz for this purpose in the United States.

Although published statistics are incomplete, it appears that the United States, India, and the Republic of South Africa are the leading world producers of kyanite-group minerals. It can be presumed that the U.S.S.R. and perhaps a few other industrialized nations also produce significant quantities of these materials.

U.S. kyanite estimated production in both 1978 and 1979 increased slightly in tonnage and value. Export and import data since 1977 for kyanite and mullite-containing materials are no longer collected as a separate category by the Bureau of the Census.

NL Industries, Inc., announced in late 1978 the sale of its Taylor Refractories Division to Didier Werke of Wiesbaden, Federal Republic of Germany. The sale of the division and related assets amounted to approximately $32 million. Taylor produces mullite and other special refractories, plus a wide range of kiln furniture, shapes, bricks, and monolithic refractories, mainly based on nonbasic materials.

Legislation and Government Programs.—The allowable depletion rates for kyanite, established by the Tax Reform Act of 1969 and unchanged through 1979, were 22% for domestic production and 14% for foreign operations.

DOMESTIC PRODUCTION

Kyanite was produced in the United States in 1978 and 1979 at three open pit mines, two in Virginia and one in Georgia. Kyanite Mining Corp. operated the Willis Mountain and East Ridge mines in Buckingham County, Va. C-E Minerals, Inc., operated the Graves Mountain mine in Lincoln County, Ga.

Estimated output of domestic kyanite in both 1978 and 1979 showed slight increases in tonnage and value. Kyanite production statistics for 1979 (and for all previous years since 1949) are withheld to avoid disclosing company proprietary data.

There are three types of synthetic mullite. Fused synthetic mullite is made by melting Bayer process alumina and silica, or bauxite and kaolin, in an electric furnace at around 3,450°F. High-temperature sintered synthetic mullite is prepared by sintering mixtures of alumina and kaolin, bauxite and kaolin, or alumina, kaolin, and kyanite above 3,180°F. Low-temperature sintered synthetic mullite is made by sintering siliceous bauxite or mixtures of bauxite and kaolin above 2,820°F.

Output of synthetic mullite in 1978 and 1979 was largely of the high-temperature sintered variety, and the four producers of this material were A. P. Green Refractories Co. at Philadelphia, Pa.; C-E Minerals, Inc., at Americus, Ga.; Didier Taylor Refractories Corp. at Greenup, Ky.; and Harbison-Walker Refractories Co. at Eufala, Ala. Electric-furnace-fused mullite was produced by Muscle Shoals, Electrochemical Div., at Tuscumbia, Ala. (in 1978), and The Carborundum Co. at Niagara Falls, N.Y.

Table 1.—Synthetic mullite production in the United States

Year	Quantity (short tons)	Value (thousands)
1975	24,150	$3,350
1976	42,230	5,453
1977	40,280	5,283
1978	38,080	5,442
1979	40,660	6,675

CONSUMPTION AND USES

Conforming to established end use patterns, kyanite and related materials were consumed in 1978 and 1979 mostly in the manufacture of high-alumina or mullite-class refractories and in lesser quantities as ingredients in some ceramic compositions. Domestic kyanite, already ground to minus 35 mesh as required by the flotation process used in its separation and recovery, was marketed either in the raw form or, after heat treatment, as mullite, which was sometimes further reduced in particle size before use. In the 35- to 48-mesh range, the mineral was used mostly in monolithic refractory applications such as for high-temperature mortars or cements, ramming mixes, and castable refractories, or with clays and other ingredients in refractory compositions for making kiln furniture, insulating brick, firebrick, and a wide variety of other articles. More finely ground material, minus 200 mesh, for example, was used in body mixes for sanitary porcelains, wall tile, investment-casting molds, and miscellaneous special-purpose ceramics.

PRICES

Engineering and Mining Journal, December 1978 and 1979, listed prices for kyanite, f.o.b. Georgia, ranging from $63 to $117 per short ton for bulk shipments and $9 more per ton for bagged material.

Price ranges quoted for kyanite-group materials in Ceramic Industry magazine, January 1979 and 1980, follow:

	Per short ton	
	1978	1979
Mullite, calcined kyanite	$105-$114	$105-$114
Mullite, calcined	105- 139	139
Mullite, fused	725- 810	725- 810

The December 1978 and 1979 issues of Industrial Minerals (London) quoted kyanite-group price ranges approximately equivalent to the following (converted from pounds sterling per metric ton to dollars per short ton):

	Per short ton	
	1978	1979
Andalusite, Transvaal, bagged, c.i.f. main European port	$164	$190
Kyanite, South African, graded, c.i.f. main European port	NA	220
Kyanite, Indian, f.o.b.	140	NA
Sillimanite, Indian, natural, bagged, f.o.b.	195	NA
Kyanite, Indian, calcined, f.o.b. Calcutta	240	NA

NA Not available.

FOREIGN TRADE

Export data of kyanite and mullite-containing materials are no longer collected as a separate category by the Bureau of the Census. Data had been collected up until 1977, and these export figures were published in this section in what was then table 2 (U.S. exports and imports for consumption of kyanite and related minerals). However, these Census figures did not distinguish between synthetic mullite and materials that were in part mullite.

Import data for kyanite-group minerals have likewise not been collected as a separate category since 1977. From 1972 through 1976, 100 to 200 tons per year was imported, largely from India and the Republic of South Africa. In 1977, imports totaled 53 tons.

WORLD REVIEW

Brazil.—Government approval to proceed with full-scale mining was received by Cianita Serra das Araras Ltda., the company developing the kyanite deposit near Anapolis in Goias State in central Brazil. The deposit consists of kyanite boulders lying close to the surface. Measured reserves are reported as 2 million tons. The property also holds large reserves of a coarse-grained kyanite-quartz rock. Trial shipments of crushed boulder material were sent to Europe, and tests conducted by refractory manufacturers were reportedly encouraging.[2]

Germany, Federal Republic of.—Imports of kyanite-group minerals in 1976 amounted to 36,500 tons. Principal countries of origin and the share supplied were the United States, 51%; France, 14%; the Republic of South Africa, 10%; India, 10%; and the United Kingdom, 9%. In 1977, imports of kyanite-group minerals were 59,900 tons. Principal countries of origin and the amounts supplied were the United States, 48%; France, 14%; the Republic of South Africa, 14%; India, 10%; and the United Kingdom, 6%.[3]

India.—The formation of a science research complex at a cost of $10 million was authorized by the Government. The project, to be set up in Orissa State under the supervision of the Government-owned company, Indian Rare Earths, will investigate the possibility of mining and processing beach sands to produce sillimanite and other minerals.[4]

The Government of India established a working group to assess important nonmetallic minerals and suggest the most feasible program for their development. The working group has opposed indiscriminate export of kyanite and sillimanite, and has recommended that production of kyanite should match the domestic requirements.[5]

Rhodesia, Southern.—Northeastern Rhodesia may contain significant resources of kyanite in four main localities: Inyanga North, Ky Mine, Madecheche, and Masterpiece. The mineral is in the form of bladed crystals at all four locations; small occurrences of massive kyanite are found only at Inyanga North.

The geological environment is similar at all localities; however, there are certain important differences. The Ky Mine deposit contains biotite-kyanite schist. Since biotite is the only primary gangue mineral, beneficiation is not difficult. Average Al_2O_3 content is 61%. At Madecheche, the ore is biotite-garnet-kyanite schist with various amounts of quartz. Beneficiation is required to remove the garnets, and the kyanite contains from 58% to 62% Al_2O_3. The grade of kyanite at Masterpiece is variable along an 11-mile strike, and beneficiation or fine grinding would be necessary to remove surface coatings of iron oxide and inclusions of graphite and biotite. Although the Inyanga North deposits are not well known, their grade is reported to be commercially acceptable.[6]

South Africa, Republic of.—Kyanite is one of several nonmetallic minerals considered to have a degree of promise for potential production in the State of Kwazulu in Natal Province.[7]

United Kingdom.—Imports of kyanite-group minerals in 1977 amounted to 69,970 tons. Principal countries of origin and the share supplied were the Republic of South Africa, 67%; the United States, 21%; and France, 11%.[8]

Table 2.—Kyanite, sillimanite and related materials: World production, by country[1]

(Short tons)

Country[2] and commodity	1976	1977	1978[p]	1979[e]
Australia: Sillimanite[3]	625	606	780	800
Brazil: Kyanite	282	121	[e]1,500	1,500
France: Kyanite-andalusite	19,986	[r] [e]22,000	[e]22,000	NA
India:				
Andalusite	--	427	248	250
Kyanite	[r]53,770	46,433	31,101	30,000
Sillimanite	16,379	16,560	14,655	15,000
Korea, Republic of: Andalusite	573	127	67	50
South Africa, Republic of:				
Andalusite	85,389	124,645	123,508	[4]147,905
Sillimanite	28,366	17,036	10,516	[4]21,577
Spain: Andalusite[e]	[r]6,330	[r]7,300	6,600	6,600
United States:				
Kyanite	W	W	W	W
Synthetic mullite	42,230	40,280	38,080	[4]40,660

[e]Estimate. [p]Preliminary. [r]Revised. NA Not available. W Withheld to avoid disclosing company proprietary data.

[1]Owing to incomplete reporting, this table has not been totaled.

[2]In addition to the countries listed, a number of other nations produce kyanite and related materials, but output is not reported quantitatively and no reliable basis is available for estimation of output levels.

[3]In addition, sillimanite clay (also called kaolinized sillimanite) is produced, but output is not reported quantitatively, and available information is inadequate for the formulation of reliable estimates of output levels.

[4]Reported figure.

TECHNOLOGY

The expansion of kyanite when calcined to form mullite was studied in laboratory work. The apparent linear expansion of 35-mesh kyanite is approximately 28%. This value decreases gradually as the mesh size decreases until it becomes about 7% for 325-mesh kyanite.[9]

New Mexico kyanite samples assaying 23% kyanite or higher can, reportedly, be treated to give a high-grade concentrate. The flowsheet is relatively simple but is sensitive to mesh size and pH control. The deposit, near Petaca, N. Mex., appears to involve a considerable tonnage of high-grade kyanite.[10]

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[1] Physical scientist, Section of Nonmetallic Minerals.

[2] Industrial Minerals (London). Green Light For Kyanite. No. 133, October 1978, p. 11.

[3] ———. Industrial Minerals of West Germany. No. 131, August 1978, p. 17.

[4] ———. Company News and Mineral Notes. No. 129, June 1978, p. 57.

[5] ———. Indian Minerals. No. 140, May 1979, p. 13.

[6] ———. Industrial Minerals of Rhodesia. No. 126, March 1978, p. 105.

[7] Page 56 of work cited in footnote 3.

[8] Industrial Minerals (London). UK Mineral Processors, Merchants, and Agents. No. 127, April 1978, p. 18.

[9] Brown, J. J., Jr. Effect of Particle Size on the Apparent Expansion of Kyanite During Conversion. Am. Ceram. Soc. Bull., v. 58, No. 6, June 1979, pp. 617, 619.

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Lead

By John A. Rathjen[1] and T. John Rowland[2]

U.S. mine output of recoverable lead dropped to 530,000 tons in 1978 and to 526,000 tons in 1979. Primary refinery output of lead from domestic and foreign raw materials, including lead in antimonial lead, increased to 568,000 tons in 1978 and 578,000 tons in 1979. Secondary smelter production increased in 1978 and 1979.

U.S. stocks of refined and antimonial lead at primary plants and consumer stocks of soft lead, and lead in antimonial lead rose sharply in 1979.

In the 1978-79 period, the U.S. producer price for lead ranged from a low of 31 cents per pound in the second quarter of 1978 to a record high of 61 cents per pound in October 1979, then declined to 55 cents at the close of the year. The lead price on the London Metal Exchange (LME) experienced a similar trend, beginning 1978 at 30.0 cents per pound and rising to a high of 63 cents in June 1979, then declining to 53 cents per pound at yearend.

World mine production of lead in concentrates increased for the third consecutive year in 1979. Total metal production from world smelters in 1979 increased to 5.5 million metric tons, continuing a growth trend which began in 1977. Total world consumption of refined primary and secondary metal increased to 5.3 million tons in 1978 and continued upward in 1979 to a total of 5.7 million tons. Total world stocks excluding those in centrally planned economy countries, declined in 1978 and 1979 from the levels established in the preceding years.

Legislation and Government Programs.—The General Services Administration retained its stockpile goal of 785,000 tons for lead in 1978 and 1979.

On October 5, 1978, the Environmental Protection Agency (EPA) issued final rules governing the National Air Quality Standard for lead. The standard restricts lead in air to 1.5 micrograms per cubic meter averaged over a 90-day period. The full economic impact of this ruling was not quanified; however, an EPA economist indicated that the ruling could virtually wipe out the secondary lead sector if the standard were fully implemented.

On November 14, 1978, the Occupational Safety and Health Administration (OSHA) issued final standards regulating occupational exposure to lead. The rules call for a maximum exposure of 50 micrograms of lead per cubic meter of air based on an 8-hour time-weighted average at the workplace. Various segments of the industry will be given different compliance schedules, which range from 1 to 10 years, to fully meet the standards. Two suits in opposition to the standards were filed with the U.S. Circuit Court. In one, the Lead Industries Association (LIA) claimed that the standard was so costly as to be prohibitive. The United Steelworkers of America (USW) claimed that the standard was not a sufficient safeguard, and that a 40-microgram limit should have been established.

The twenty-third and twenty-fourth sessions of the International Lead and Zinc Study Group (ILZSG) were held in Geneva, Switzerland, November 23-30, 1978, and October 4-11, 1979, respectively. It was projected that both mine and smelter production would increase marginally in 1979, and that surplus would be absorbed by demand from the central economy countries. Little growth was foreseen in market economy lead metal consumption.

The Department of Energy (DOE) sponsored the third Electric and Hybrid Vehicle (EHV) Program in Arlington, Va., on June 25-27, 1979. The meeting addressed all phases of the EHV program with considerable emphasis on the lead-acid storage battery, which is currently the accepted power supply for electric vehicles.

Table 1.—Salient lead statistics

(Metric tons unless otherwise specified)

	1975	1976	1977	1978	1979
United States:					
Production:					
Domestic ores, recoverable lead content	563,783	552,971	537,499	529,661	525,569
Value thousands	$267,230	$281,613	$363,789	$393,516	$609,929
Primary lead (refined):					
From domestic ores and base bullion	481,003	515,767	486,659	501,643	529,970
From foreign ores and base bullion	96,077	76,513	62,041	63,530	45,641
Antimonial lead (primary lead content)	1,928	4,211	2,987	2,914	2,596
Secondary lead (lead content)	597,341	659,132	757,592	769,236	801,368
Exports (lead content):					
Lead ore and concentrates	NA	NA	NA	54,231	32,902
Lead materials excluding scrap	19,283	5,332	8,931	8,225	10,646
Imports, general:					
Lead in ore and matte	79,433	69,277	66,533	52,985	39,998
Lead in base bullion	419	2,117	7,319	4,307	1,681
Lead in pigs, bars, and reclaimed scrap	96,049	136,391	243,164	226,926	198,344
Stocks December 31 (lead content):					
At primary smelters and refineries	142,002	110,406	91,113	98,665	89,322
At consumers and secondary smelters	120,941	117,580	121,387	125,234	153,195
Consumption of metal, primary and secondary	1,176,708	1,351,771	1,435,473	1,432,744	1,358,335
Price: Common lead, average, cents per pound[1]	21.53	23.10	30.70	33.65	52.64
World:					
Production:					
Mine thousand metric tons	3,432.1	[r]3,302.8	[r]3,406.4	3,444.7	3,512.7
Smelter[2] do	3,295.9	[r]3,370.3	[r]3,395.1	3,469.4	3,534.9
Secondary smelter do	1,245.1	1,673.1	1,944.7	1,872.8	1,937.3
Price: London, common lead, average, cents per pound	18.73	20.46	28.00	29.86	54.52

[r] Revised. NA Not available.

[1] Quotation on a nationwide, delivered basis.

[2] Primary metal production only. Includes secondary metal production where inseparably included in country total.

DOMESTIC PRODUCTION

MINE PRODUCTION

U.S. mine output of recoverable lead dropped in 1978 and 1979. This was the fifth consecutive annual decline from the record high level achieved in 1974. Production from Missouri mines increased in 1978 and 1979, accounting for 87% of the total in 1978 and 90% in 1979. Mine production in Idaho increased in 1978, but decreased in 1979, maintaining Idaho's position as the second largest lead-producing State. Lead production in Colorado declined in 1978 and 1979 largely due to curtailed operations at the Idarado, Leadville Unit, Sunnyside, and Eagle mines. Output of lead in Utah dropped to a low of 2,500 tons in 1978, and in 1979 there was virtually no production since the major producers had closed down.

For the ninth consecutive year, the Buick mine, jointly owned by AMAX Lead Co. of Missouri and Homestake Lead Co., was the Nation's leading lead producer. Tonnage of ore milled in 1978 totaled 1.31 million tons averaging 9.2% lead. In 1979 a record 1.81 million tons of ore was mined and milled averaging 7.8% lead. The quantity of ore milled in 1978 was lower than that of 1979 because of a strike which lasted from June 1 through mid-August 1978. Lead concentrates produced totaled 151,883 tons in 1978 and 178,937 tons in 1979. Total recoverable ore reserve was estimated to be 43.5 million tons, with an average grade of 6.1% lead. The principal areas to be mined are held under long-term Federal mineral leases which expire in the year 2013.

St. Joe Lead Co., a subsidiary of St. Joe Minerals Corp., the Nation's largest lead-producing company, operated six mines and four mill complexes in southeast Missouri during 1978 and 1979. The company reported that its mines produced 222,395 tons of lead in concentrates in 1978 compared with 221,745 tons of lead in concentrates in 1979.

Hecla Mining Co. reported that its Lucky Friday mine produced 143,880 tons of ore assaying 11.0% lead in 1978, and 159,574 tons of ore assaying 11.5% lead in 1979. Ore reserves at yearend were 531,000 tons compared with 544,311 tons at the end of 1978. Hecla also reported production from the Star-Morning mine, jointly owned by Hecla (30%) and The Bunker Hill Co. (70%), totaling 263,265 tons of ore in 1978, and 257,731 tons in 1979. Computed ore reserves were approximately 907,000 tons at the end of 1978 and about 1.36 million tons at yearend 1979. The increase in ore reserves resulted from both the development of new ore on the lower levels of the mine and from higher metal prices which lowered the cutoff grade of ore for mining.

The Bunker Hill Co., a subsidary of Gulf Resources & Chemical Corp., reported that production from company owned and controlled mines totaled 25,401 tons of lead, about 3,600 tons more than in 1978. Proven and probable ore reserves in the Bunker Hill mine totaled 2.08 million tons at yearend 1979.

The Idarado Mining Co. in Colorado mined and milled 163,747 tons of ore averaging 2.63% lead during 1978. Ore reserves at yearend 1978 were 2.62 million tons. In July 1978, operations were suspended because of continuing depressed metal prices and high charges for smelting and refining. Mining and milling ceased on November 9 after all broken ore was processed, and the property was placed on care-and-maintenance status.

SMELTER AND REFINERY PRODUCTION

Output of primary refined lead and lead in antimonial lead from the five primary refineries in 1978 was slightly higher than that of 1977. In 1979 the total production increased to 581,604 tons. About 89% of the total refined lead produced in the 2-year period was corroding-grade lead, the remaining production was in common, chemical, antimonial, and miscellaneous specification metal.

St. Joe Lead Co.'s smelter-refinery produced 218,001 tons of lead in all forms in 1978 and 203,292 tons in 1979. The smelter processed ore and concentrates from mines in the United States, Mexico, and Peru. The Bunker Hill smelter-refinery produced 99,790 tons of refined lead in 1978, and 91,354 ton in 1979. The smelter processed ore and concentrates from mines in the United States, Mexico, and Peru. Completion of a tall stack at the smelter in 1978 enabled the company to meet Federal air quality standards for sulfur dioxide and will permit the plant to operate near capacity levels in the future.

ASARCO Incorporated reported that its Omaha, Nebr., and Glover, Mo., refineries produced 162,930 tons of lead in 1978 and 164,110 tons in 1979. As a custom smelter, approximately 4% of refined metal production was accountable to materials produced by ASARCO's mines and associated companies, 82% to purchased materials, and 14% to material processed from others on a toll basis. The East Helena, Mont., and El Paso, Tex., lead smelters process complex concentrates and other lead-bearing materials from domestic and foreign sources. El Paso's new 725-ton-per-day sulfuric acid plant to control sulfur dioxide emissions was tested in the fourth quarter of 1978. A new lead ore roasting furnace, or sinter plant, was completed and placed in operation in mid-1979. These two smelters are expected to supply increased amounts of crude lead to the Omaha lead refinery. ASARCO's Glover plant processed relatively pure lead concentrates from the Missouri lead belt. Because of problems with the blast furnace, production of refined lead in 1978 fell short of capacity, but returned to normal in 1979.

The AMAX-Homestake smelter-refinery at Boss, Mo., treated 151,882 tons of lead concentrate from the Buick and Magmont mines and produced 93,126 tons of refined lead in 1978. Totals in 1979 were 178,936 and 121,128 tons, respectively. The difference was attributed to a 70-day strike which stopped production in 1978.

Secondary smelter production from recycled materials established a record of 801,368 tons in 1979. Secondary lead accounted for 58% of the total smelter and refinery lead output. Approximately 113 secondary plants operated intermittently in recovering lead and lead alloys from processing scrap materials during 1979. A major change in the secondary lead industry occurred during 1979 as NL Industries, Inc., the largest producer, began divesting itself of its lead plants. By yearend NL retained only the plants in Atlanta, Ga., and Pedricktown, N.J. Some of the buyers included Gould, Inc., Seitzingers, Inc., and Associated Lead Smelters Inc. Expansion plans and acquisitions were announced by other companies and it was expected that further change will take place in the industry during 1980.

RAW MATERIAL SOURCES

Primary smelters and refineries processed ores and concentrates from domestic mines yielding 504,027 tons of refined lead and antimonial lead in 1978 and 532,461 tons during 1979. Lead refined and recovered from imported concentrates in 1978 totaled 64,060 tons. In 1979 imports of concentrates dropped sharply to 45,746 tons and was attributed to the increased production at Missouri mines. Lead recovered from scrap processed at primary plants was 2,626 tons in 1978, increasing to 3,397 tons in 1979.

Scrap materials consumed totaled 1,062,301 tons in 1978 and 1,105,130 tons in 1979. New scrap accounted for 16% of the total scrap processed in 1978, compared with 17% in 1979. The remainder, old scrap, was largely battery plates with smaller quantities of cable lead, soft and hard lead, type metal, solder, and babbitt. A small quantity of reclaimed scrap totaling 3,307 tons in 1978 and 4,006 tons in 1979 was imported for processing in domestic plants.

CONSUMPTION AND USES

Domestic consumption of lead declined in 1978 and 1979.

In 1979, the Bureau of Mines began reporting consumption on a basis of the Standard Industrial Code (SIC). In the category of metal products consumption declined in 1979 mainly because of the drop in use of lead for manufacture of storage battery grids and oxides. The reduction was attributed to the mild winter and drawdown of metal and battery stocks which had accumulated in the past several years of severe weather conditions. Production cutbacks in the automotive industry were also a factor in lesser use for lead metal products. There were slight declines in use for ammunition and building materials although consumption for cable coverings and brass and bronze registered modest increases. The general category of pigments declined nominally, but chemicals for petroleum refining which had been sliding downward due to EPA regulations increased 9,000 tons to about 187,000 tons in 1979.

LEAD PIGMENTS

Consumption of pig lead in the manufacture of lead oxides and pigments totaled 541,215 tons in 1978 and 546,342 tons in 1979. Production of black oxides for battery manufacture consumed the largest portion of the lead and accounted for 77% of the total lead used in 1978, and 81% in 1979. Production and consumption of red lead and other basic lead chemicals remained fairly stable in 1978 and 1979; however, litharge production dropped sharply in 1979 as requirements for battery manufacture decreased.

Prices.—When the basic selling price for pig lead was quoted at 33, 48, 58, and 63 cents per pound, the published price for red lead, 97%, was 46.5, 57.5, 67.5 and 72.5 cents per pound, respectively. Using the same pig lead base prices, the comparative selling prices for litharge were 43.5, 54.5, 64.5, and 69.5 cents per pound. The pricing of lead chemicals and pigments has been altered from the traditional pattern of set premiums in effect for many years. As the number of producers and their product mix have changed, the prices of various products have been adjusted accordingly. The quoted price for lead chemicals in 1978 and 1979 was based on the selling price for pig lead in a given period; however, premium adjustments were made by the individual companies and reflect differences in manufacturing technique, freight considerations, quality requirements, and other factors. The decision by some battery manufacturers to produce and sell lead oxide also had an effect on the price mechanism. As a result, there was a range of prices available and each producer or consumer made arrangements best suited to its requirements.

Foreign Trade.—Imports of lead pigments and chemicals for consumption increased slightly in 1978 and then declined to 19,718 tons in 1979. The major portion of the imports was litharge and red lead, which were imported from Mexico, and a substantial portion of lead chromate, also called chrome yellow, which came from Canada. Small quantities of other lead pigments and chemicals were imported from producers in Europe.

PRICES

The U.S. producer price of lead declined from 33 cents to 31 cents per pound in May 1978, but recovered in mid-August to 33 cents. In a series of increases the price rose to 38 cents per pound in November, where it remained for the balance of the year. In January 1979 the price averaged 40.8 cents per pound, and then escalated steadily during the year to a record high average of 61 cents per pound in October. The sharp increase was attributed to a worldwide shortage of lead concentrates and a strong demand for physical metal from central economy countries. The price tapered off in November and December. In terms of U.S. currency, the LME monthly average cash price in 1978 ranged from 30.0 cents in January to a low of 24.7 cents in May, then increased to about 38.9 cents at yearend. The January 1979 price averaged 45 cents per pound signaling the beginning of an escalation which peaked at 62.6 cents per pound in June. The LME price then began a downward trend from 57.6 cents per pound in July to 53.3 cents in December. The 1979 yearly average price was 54.5 cents per pound, a disparity of 1.9 cents from the average U.S. producer price which is usually from 3 to 4 cents higher than the LME, representing the costs of duty and freight to the United States.

FOREIGN TRADE

Exports of lead metal, lead alloys, and lead scrap increased in 1978 and 1979. The major portion of the exports in 1978 went to Canada, the Republic of Korea, and Mexico in the form of scrap. In 1979 these countries continued as important markets with Taiwan also becoming a large consumer of scrap. Exports of lead in ore and concentrates were also an important factor in 1978 and 1979. Brazil and the U.S.S.R. were the largest recipients, followed by Mexico and Canada.

General imports of lead in 1979 were down considerably from the totals reported in 1977 and 1978. Following traditional patterns, the largest imports were in pigs and bars including bullion, followed by lead in ores and concentrates, and lastly, reclaimed scrap. The principal source countries for metal were Canada, Mexico, and Peru, supplemented by smaller tonnages from 17 other countries. Lead in ores and concentrates was supplied mainly from Canada, Mexico, and Peru with lesser shipments from eight other countries.

Basic tariff rates continued through 1979 at 0.75 cent per pound on lead in ore and concentrates and 1.0625 cents per pound on bullion, metal, and dross, for favored nations, and at 2.125 cents per pound statutory for other nations.

As a result of the Tokyo Round of tariff negotiations completed in 1979, new agreements on tariffs were reached with the developed nations of the world. The agreements now place most nations on a most-favored-nation (MFN) basis with lower rates to be phased in over an 8-year period beginning January 1, 1980. The new tariff schedules are as follows, on lead content basis:

	Number	Most Favored Nation (MFN)		Non-MFN
		1/1/80	1/1/87	
Ore	602.1	0.75 cent/lb	0.75 cent/lb	1.5 cent/lb
Lead bullion	624.02	3.5% ad val.	3.5% ad val.	10.5% ad val.
Other unwrought	624.03	3.5% ad val.	3.5% ad val.	10% ad val.
Waste and scrap	624.04	3.6% ad val.	2.3% ad val.	11.5% ad val.

WORLD REVIEW

World mine production of lead in 1978 was 3.4 million tons, unchanged from 1977 and about 0.1 million tons less than the total 3.5 million tons registered in 1979. Refined metal production including secondary refined metal was 5.20 million tons in 1978 and 1979 as reported by the World Bureau of Metal Statistics. Centrally planned economy countries were estimated to contribute 1.2 million tons to the total.

Australia.—A rise in production in 1979 was attributed to increased output at the Woodlawn project near South Wales and a return to normal production levels at Mount Isa and the New Broken Hill Consolidated (NBHC) mine at Broken Hill. The increase in smelter-refinery production in 1979 reflected the need to meet increased worldwide sales commitments. Australian consumption of lead was about 72,000 tons in 1978 and 1979.

In 1978, production began at the open pit mine at Woodlawn near Goulburn, New South Wales. The deposit had reserves of 10 million tons of ore containing lead, zinc, copper, and silver. Full production was achieved in 1979.

Mt. Isa Mines Ltd. (MIM) continued development of the Hilton mine north of the Mt. Isa lode and announced the development of a trial slope project, to be operative by 1984-85. A pilotplant study at the McArthur River lead-zinc ore body was completed in 1978. Both NBHC and MIM announced during 1979 that they would each spend in excess of $10 million upgrading their preparation and concentrating facilities to improve productivity. Work is scheduled to be completed by 1983.

In mid-1979 Simsmetal completed construction of a new secondary lead smelter in Sydney. The new plant was rated at 11,500 tons of lead per year.

Bolivia.—A contract was signed between Bolivia and a European consortium composed of Klockner-Industrie-Anlagen, Klockner-Humboldt-Deutz, Mechim and Sidech (Belgium), and Klockner-Belge for a lead and byproduct smelter. The smelter-refinery was designed to produce up to 24,000 tons of lead per year with byproducts including silver, antimony, tin, zinc, copper matte, and bismuth. The startup date was set for mid-1982.

Brazil.—An active exploration program was implemented in order to replenish the diminishing reserves at some of the mines. One of the projects was the exploration of a deposit in the Chapada do Ariripe in Northern Bahia. The Cretaceous age bed is only 45.9 centimeters thick but extends over an area of more than 1 thousand square kilometers. In 1979 Cobrac-Plumbum of Brazil announced plans to expand refined lead output from 52,000 tons to 60,000 tons in 1980 and 93,000 tons in 1982. The company operated mines at Cobrac, Bahia, and Plubum, Parana, but imported 60% of its lead concentrates.

Canada.—Domestic consumption patterns of lead were 50% batteries, 22% chemicals, 20% alloys and semifabricated products, and 8% miscellaneous.

The HB mine of Cominco Ltd. in British Columbia closed on September 1, 1978, due to the exhaustion of reserves. ASARCO had planned to close the Buchans mine in central Newfoundland in mid-1979 but continued to operate in view of the high price for lead which prevailed through the year. In New Brunswick the $53 million expansion program at the No. 12 mine of Brunswick Mining and Smelting Corp. Ltd., which was deferred in 1977, was rescheduled for completion in 1980.

Two new mines were under development in Nova Scotia in 1978. The Gays River mine of Esso Minerals Canada began production in late 1979 at a planned rate of production of 17,000 tons per year of lead concentrate assaying 72% lead. The Yaa mine owned by Barymin Exploration Ltd., located on Cape Breton Island, started production in mid-1979 with an expected annual production of 10,000 tons of lead in concentrate.

Germany, Federal Republic of.—In 1978, four lead-zinc mines supplied ore to five concentrators. Preussag AG mined half of the lead-zinc ores in the Harz region. Sachtleben Bergbau GmbH recovered about 40% of the total production at Lennestadt in the North Rhine Westphalia region. The balance came from the Luderich mine of AG des Altenbergs in the Cologne region. Late in 1978 the Luderich mine was closed. As a result, one of Germany's five concentrators was also shut down. The concentrator could have been kept operative with the opening of a new mine in Bensberg but this was not possible because of legal actions and protest by environmental protectionists and citizens groups.

Smelter and refinery production of primary and secondary materials in 1978 was 305,000 tons of lead. The output was increased during 1979 to a total of about 342,000 tons. The principal operator in 1978 was Berzelius Metallhutten GmbH's Imperial Smelter at Duisburg Wanheim with an annual capacity of 35,000 tons. In 1978, Preussag-Boliden-Blei GmbH temporarily closed the Harz, Lower Saxony, lead smelter because of a shortage of lead concentrates. Usually, about 40% of the concentrates are supplied by Boliden, AB while the remainder is acquired by Preussag from various foreign sources, principally Canada.

India.—In 1978, a new lead smelter was commissioned at Visakhapatnam with an annual capacity of 10,000 tons. The refinery at Tundoo in Bihar was expanded to a capacity of 8,000 tons per year. Construction work began in 1978 to develop the lead deposits at Sargipalli in Orissa, where reserves were estimated at over 2 million tons of ore. Lead concentrates containing 65% lead as lead sulfide will also be available from the Zawar mine in Rajasthau and Agnigundala mines in Andhra Pradesh.

Ireland.—Mine production of lead in 1978 was greater than in 1977 as Tara Mines Ltd. completed the first full year of operation at Navan, County Meath. Treatment of over 1.5 million tons of ore produced 41,800 tons of lead concentrates with a metal content of

28,700 tons.

Northgate Exploration Ltd.'s lead-zinc-copper-zinc mine at Tynagh, County Galway, was affected by a labor dispute which stopped operations throughout the second half of 1978. Output of ore was only 41% of that of the previous year. Ore reserves at Tynagh were reported at 818,300 tons.

Development plans of the proposed open pit mine at the Bula lead-zinc ore body at Navan requires the diversion of the River Blackwater. A study of the implications of the river diversion was completed at yearend 1978.

Mexico.—Industrial Minera Mexico, S.A. (IMM) increased the capacity of its concentrator at the Santa Barbara, Chihuahua, unit from 2,400 tons to 3,000 tons of ore per day. However, production was curtailed during 1978 due to flooding in one of the mines. The Naica mine of Cia. Fresnillo in Chihuahua completed modifications and increased production during 1978. In 1979 Minera Real de Angeles SA de CV decided to place its silver-lead-zinc property into production. Placer Development Ltd. holds a 34% interest in the venture along with the Mexican Government and Frisco SA de CV, a Mexican mining company. Estimated cost of the project is US$150 million.

The Real de Angeles property, in the State of Zacatecas, Mexico, has estimated reserves of 59 million tons, with an average grade of 1% lead, 0.9% zinc, 0.015% cadmium, and 73 grams per ton of silver. A 10,000-ton-per-day concentrator will be built to produce silver-lead, zinc-cadmium concentrates beginning in 1982.

Morocco.—In 1978, production of lead concentrates continued with a shipment of 30,000 tons processed in Morocco by the lead smelter at Cued El Heimer. Expansion of the smelter was underway to increase capacity to 48,000 tons of lead metal per year. At yearend 1979 a new lead-zinc-tungsten mine was opened at Draa Sfar near Marrakesh. Initial annual production was expected to be 3,000 tons of lead concentrate.

Peru.—A complete overhaul of the lead sinter plant at the smelter in La Oroya was in progress in 1978 with the basic engineering being provided by Kaiser Engineers. The output of refined lead increased in 1979 with the completion of repairs at the smelter. Centromin produced about one-third of the total lead mine output. Centromin's major producing mine was the Cerro de Pasco and the sole refinery was at La Oroya. Other substantial lead mines were the Atacocha, Buenaventura, Milpo, Huaron, Raura, and San Ignacio de Morococha.

South Africa, Republic of.—Phelps Dodge Corp. had holdings on three ore deposits in northwest Cape Province which reportedly could make South Africa a significant lead producer. Reports indicated that the Broken Hill ore body contains 38 million tons of ore averaging 6.35% lead, 2.87% zinc, 0.45% copper, and 89.1 grams of silver per ton. The Broken Hill deposit was under continuing development in 1979 with mine production expected to begin by 1980. Mining at Broken Hill will be by underground methods. Two ore bodies comprise the deposit, the upper and lower, consisting of massive sulfide and mineralized schist with abundant galena and pyrrhotite. The mill was planned to produce 132,000 tons of lead concentrates, 35,000 tons of zinc concentrates, 22,000 tons of copper concentrates, and 120,000 kilograms of silver per year. The Black Mountain deposit was reported to contain reserves of 86 million tons of ore averaging 0.72% copper, 2.67% lead, 0.56% zinc, and 27.4 grams of silver per ton. The Black Mountain Mineral Development Co., Ltd. project, owned 51% by Gold Fields South Africa Ltd. and 49% by Phelps Dodge Copper Corp., is slated to start producing 132,000 tons of lead annually in 1980. The other deposit, Big Syncline, had reserves of 101 million tons, averaging 0.04% copper, 1.01% lead, 2.45% zinc, and 13.7 grams of silver per ton.

In Gamsberg, Northern Cape region, the Gamsberg lead-zinc mines were under construction by a consortium including Anglo-American Corp., Newmont Mining Corp., and O'Okiep Copper Company Ltd. Further development was deferred during 1979 pending an improvement in zinc markets.

At the end of 1979, ore reserves at Gamsberg were recalculated by the operators at 152,533,400 tons at 7.11% zinc and 0.55% lead, compared to 150,384,000 tons at 7.10% zinc and 0.55% lead at the end of 1978.

Yugoslavia.—In 1978, about 21 mines, 14 flotation plants, 2 lead smelters, the Trepca-Zvecan and Mezica, and the Trepca-Zvecan lead refinery were operational. Several mines and mills were being expanded in 1978. The most significant was the expansion of Trepca's annual capacity from 650,000 to 1,000,000 tons of ore. Output of lead concentrates should increase to 65,000 tons. The Trepca combine of Kosovska Mitrovica began expansion of the Kopaonik lead-zinc mill at Leposavic, northwest of Kosovska Mitrovica, Serbia. A new mine, operated by Veliki Majdan, started production in 1978 at Tisovik near Osecina, Serbia. The annual capacity was reported at 4,500 tons of direct shipping ore containing 1,500 tons of lead. The ore was to be shipped to the smelter at Trepca. Work continued on expansion and modernization through 1979, and plans were announced for a new lead smelter at Trepca which is to produce 170,000 tons of lead annually.

TECHNOLOGY

Metallurgists at the Bureau of Mines Reno Research Center continued process evaluation on the aqueous electrolysis of lead chloride under a cost-sharing cooperative research program with four major lead producers. To avoid sulfur dioxide and lead vapor emissions, the Bureau of Mines developed a method for producing lead by leach-electrolysis as an alternative to pyrometallurgical smelting. The method involves leaching galena concentrate with a solution of ferric chloride and sodium chloride to produce lead chloride, and converting the lead chloride to lead metal by fused-salt electrolysis. A process development unit designed to produce 500 pounds of lead metal per day was operated intermittently in 1979 without major operating problems. Lead concentration in workplace air was monitored continuously. Lead exposure was well below the permissible exposure limit of 50 micrograms of lead per cubic meter of air. Operating personnel had lead-in-blood levels ranging from 7 to 26 micrograms of lead per 100 grams of whole blood, which is well below the OSHA standard of 40 micrograms of lead per 100 grams of whole blood.[3]

At the Reno Research Center the Bureau of Mines continued investigation of an electrolytic procedure for refining Missouri lead bullion. The procedure being investigated was more energy efficient and environmentally acceptable than conventional pyroprocessing. By adding 1% lead to the lead bullion or using anode bags to collect loose slimes formed on anodes without added lead, the resulting electrorefined products analyzed 99.999% and 99.99% lead, respectively. Energy consumption was low, at 70 to 90 kilowatt-hours per metric ton of refined lead, and the current efficiency was near 100%.[4]

The Bureau also investigated a hydrometallurgical procedure to conserve cobalt, nickel, and copper by recovering the metal from the matte byproducts of smelting Missouri lead ores. For want of adequate processing technology the mattes are now either unmarketable or marginally so. The procedure involves leaching with manganese dioxide and sulfuric acid to obtain copper, nickel, cobalt, lead, and manganese sulfates, and elemental sulfur.[5]

The possibility of utilizing batteries in load leveling applications and other storage possibilities has been the focus of research in several areas. Opportunities to combat the growing oil shortage were investigated such as energy storage in electric-power systems, in transportation, and in commercial and residential structures. The Electric Power Research Institute and the Department of Energy jointly financed a battery energy storage test which the Newark, N.J., Public Service Electric & Gas Co. cosponsored. A favorable time of day is sought for battery recharging for electric vehicles.[6]

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[1] Mineral specialist, Section of Nonferrous Metals.

[2] Physical scientist, Section of Nonferrous Metals.

[3] Haver, F. P., D. L. Bixby, and M. M. Wong. Aqueous Electrolysis of Lead Chloride. BuMines RI 8276, 1978, 11 pp.
U.S. Bureau of Mines. Research 79. 1980, p. 43.

[4] Lee, A. Y., E. R. Cole, Jr., and D. L. Paulson. Electrorefining Missouri Low-Antimony Lead Bullion. BuMines RI 8401, 1979, 15 pp.

[5] Sandberg, R. G., T. L. Hebble, and D. L. Paulson. Oxidative Sulfuric Acid Leaching of Lead Smelter Mattes. BuMines RI 8371, 1979, 16 pp.

[6] Kalhammer, F. Energy-Storage Systems. Sci. Am., v. 241, No. 6, December 1979, pp. 56-65.

Table 2.—Lead statistics, 1931-79

(Metric tons unless otherwise specified)

Year	United States						Price (cents per pound)[2]	World production (mine)
	Mine production	Refinery production (primary sources)	Secondary production	General imports (refined)[1]	Exports	Total consumption		
1931	367,067	401,669	212,916	9	19,654	515,009	4.24	1,325,397
1932	265,776	255,773	179,895	40	21,333	378,024	3.18	1,192,948
1933	247,968	239,203	208,663	99	20,716	407,780	3.87	1,182,969
1934	260,670	282,349	189,057	257	5,361	442,706	3.86	1,312,697
1935	300,372	294,436	245,303	1,199	6,334	488,882	4.06	1,381,643
1936	338,307	362,108	238,499	2,350	16,613	574,792	4.71	1,502,298
1937	421,743	423,943	249,567	4,448	18,226	615,706	6.01	1,690,086
1938	335,410	348,059	204,025	2,935	41,609	495,323	4.74	1,761,753
1939	375,556	439,109	219,085	6,476	67,487	605,092	5.05	1,725,466
1940	414,989	483,692	236,182	137,482	21,550	709,419	5.18	1,756,310
1941	418,599	517,973	360,530	248,740	13,026	952,544	5.79	1,618,418
1942	450,181	514,228	293,022	332,481	1,760	946,194	6.48	1,626,583
1943	411,229	426,025	310,343	221,816	1,817	1,009,697	6.50	1,448,331
1944	378,170	421,626	300,656	202,083	14,082	1,014,777	6.50	1,318,140
1945	354,556	402,414	329,344	206,356	1,277	953,996	6.50	1,181,155
1946	304,338	306,807	356,330	104,783	542	867,722	8.11	1,150,311
1947	348,560	400,078	464,452	144,708	1,382	1,063,221	14.67	1,358,963
1948	354,234	368,947	453,657	224,180	362	1,028,653	18.04	1,425,188
1949	371,862	433,034	373,926	249,694	879	868,787	15.36	1,550,379
1950	390,840	461,135	487,513	400,783	2,481	1,123,078	13.30	1,678,292
1951	352,137	378,925	470,022	162,415	1,162	1,074,826	17.49	1,714,580
1952	353,949	428,964	427,551	463,318	1,598	1,025,840	16.47	1,841,586
1953	310,841	424,464	441,561	349,331	728	1,090,077	13.48	1,905,069
1954	295,215	441,538	436,288	250,643	541	993,251	14.05	2,059,310
1955	306,651	434,684	455,453	239,632	366	1,100,092	15.14	2,204,459
1956	320,078	491,974	459,721	238,276	4,198	1,097,437	16.01	2,258,891
1957	306,824	484,013	443,821	294,181	3,936	1,032,481	14.66	2,394,968
1958	242,560	426,518	364,495	334,254	1,233	894,836	12.11	2,349,609
1959	231,964	309,287	409,492	238,967	2,500	989,874	12.21	2,331,465
1960	223,774	346,940	426,289	186,910	1,784	926,392	11.95	2,376,825
1961	237,611	407,839	410,766	233,012	1,935	931,875	10.87	2,394,968
1962	214,963	341,159	402,973	233,329	1,912	1,006,644	9.63	2,508,367
1963	229,853	358,095	447,669	205,955	987	1,055,381	11.14	2,517,681
1964	259,464	407,715	491,315	188,553	9,231	1,090,562	13.62	2,521,232
1965	273,196	379,429	522,374	201,951	7,066	1,126,254	16.00	2,691,172
1966	296,963	399,828	519,666	258,901	4,931	1,201,001	15.12	2,847,453
1967	287,515	344,634	502,374	329,851	5,929	1,143,521	14.00	2,866,109
1968	325,821	423,937	499,749	306,737	7,512	1,205,458	13.21	3,007,311
1969	461,769	579,378	547,854	252,542	4,507	1,260,405	14.93	3,235,077
1970	518,698	604,847	541,943	221,918	7,028	1,234,272	15.69	3,394,274
1971	524,852	589,684	541,405	177,434	5,375	1,298,648	13.89	3,395,548
1972	561,470	617,248	559,368	219,893	7,599	1,347,400	15.03	3,448,295
1973	547,054	611,911	598,558	161,585	60,397	1,398,162	16.29	3,486,968
1974	602,253	610,557	633,848	107,380	56,229	1,450,976	22.53	3,413,274
1975	563,783	577,080	597,341	91,182	19,283	1,176,708	21.53	3,432,141
1976	552,971	592,280	659,132	132,387	5,332	1,351,771	23.10	3,302,800
1977	537,499	548,700	757,592	237,023	8,931	1,435,473	30.70	3,406,400
1978	529,661	565,178	769,236	221,313	8,225	1,432,744	33.65	3,444,700
1979	525,569	575,611	801,368	191,662	10,646	1,358,335	52.64	3,512,700

[1] 1931-39 includes a small quantity of scrap.

[2] Quotations for 1931-71 at New York and from 1972 on a nationwide, delivered basis.

Table 3.—Mine production of recoverable lead in the United States, by State

(Metric tons)

State	1975	1976	1977	1978	1979
Alaska	--	13	--	(¹)	--
Arizona	381	307	288	416	354
California	60	49	3	W	W
Colorado	24,574	24,266	20,860	15,151	7,554
Idaho	45,718	48,658	42,872	44,761	42,636
Illinois	W	W	W	W	W
Kentucky	(¹)	--	--	W	--
Maine	330	196	161	--	--
Missouri	468,069	454,492	453,824	461,762	472,054
Montana	186	83	96	132	258
Nevada	2,700	528	674	653	24
New Mexico	1,752	W	W	W	W
New York	2,746	2,899	2,520	990	458
Oklahoma	--	W	W	--	--
Oregon	W	--	--	--	(¹)
Tennessee	--	--	--	--	(¹)
Texas	--	--	--	W	--
Utah	11,502	14,784	9,749	2,541	W
Virginia	2,314	1,765	1,998	1,803	1,596
Washington	W	W	1,090	W	(¹)
Wisconsin	W	W	W	W	W
Other States	3,451	4,931	3,364	1,452	635
Total	563,783	552,971	537,499	529,661	525,569

W Withheld to avoid disclosing company proprietary data; included in "Other States."

[1] Less than 1/2 unit.

Table 4.—Production of lead and zinc in the United States in 1978, by State and class of ore, from old tailings, etc., in terms of recoverable metal

(Metric tons)

State	Lead ore			Zinc ore			Lead-zinc ore		
	Gross weight (dry basis)	Lead content	Zinc content	Gross weight (dry basis)	Lead content	Zinc content	Gross weight (dry basis)	Lead content	Zinc content
Arizona	(1)	(1)	--	--	--	--	--	--	--
Colorado	(1)	(1)	--	--	--	--	283,338	8,388	14,266
Idaho	(1)	(1)	(1)	(1)	(1)	(1)	789,278	29,081	30,228
Missouri	7,962,153	461,762	59,038	--	--	--	--	--	--
Montana	--	--	--	--	--	--	(1)	(1)	(1)
Nevada	--	--	--	--	--	--	(1)	(1)	(1)
New Jersey	--	--	--	167,074	--	28,915	--	--	--
New York	--	--	--	392,959	990	26,463	--	--	--
Pennsylvania	--	--	--	448,736	--	19,099	--	--	--
Tennessee	--	--	--	3,291,988	--	83,968	--	--	--
Utah	(1)	(1)	(1)	--	--	--	93,370	2,435	3,496
Virginia	--	--	--	455,414	1,803	10,974	--	--	--
Other States[2]	42,747	805	4,893	155,102	223	3,228	--	--	--
Total	8,004,900	462,567	63,931	4,911,273	3,016	172,647	1,165,986	39,904	47,990
Percent of total lead-zinc	--	87	21	--	1	57	--	7	16

State	Copper-lead, copper-zinc, and copper-lead-zinc ores			All other sources[3]			Total		
	Gross weight (dry basis)	Lead content	Zinc content	Gross weight (dry basis)	Lead content	Zinc content	Gross weight (dry basis)	Lead content	Zinc content
Arizona	--	--	--	[1]44,583,434	[1]416	W	44,583,434	416	W
Colorado	180,212	4,270	7,125	[1]202,437	[1]2,493	817	665,987	15,151	22,208
Idaho	--	--	--	[1]723,690	[1]15,680	[1]2,125	1,512,968	44,761	32,353
Missouri	--	--	--	--	--	--	7,962,153	461,762	59,038
Montana	--	--	--	[1]8,409	[1]132	[1]79	8,409	132	79
Nevada	--	--	--	[1]787,727	[1]653	[1]1,371	787,727	653	1,371
New Jersey	--	--	--	--	--	--	167,074	--	28,915
New York	--	--	--	--	--	--	392,959	990	26,463
Pennsylvania	--	--	--	--	--	--	448,736	--	19,099
Tennessee	1,837,426	--	3,938	--	--	--	5,129,414	--	87,906
Utah	--	--	--	[1]4,990	[1]106	[1]13	98,360	2,541	3,509
Virginia	--	--	--	--	--	--	455,414	1,803	10,974
Other States[2]	--	--	--	600,132	424	2,634	797,981	1,452	10,755
Total	2,017,638	4,270	11,063	46,910,819	19,904	7,039	63,010,616	529,661	[4]302,669
Percent of total lead-zinc	--	1	4	--	4	2	--	100	100

W Withheld to avoid disclosing company proprietary data; included in "Other States."

[1] Lead ore, zinc ore, lead-zinc ore, and ore from "All other sources" combined to avoid disclosing company proprietary data.

[2] Other States includes Alaska, California, Illinois, Kentucky, New Mexico, Texas, Washington, and Wisconsin.

[3] Lead and zinc recovered from copper, gold, silver, and fluorspar ores, and from mill tailings and miscellaneous cleanups.

[4] Data do not add to total shown because of independent rounding.

Table 5.—Production of lead and zinc in the United States in 1979, by State and class of ore, from old tailings, etc., in terms of recoverable metal

(Metric tons)

State	Lead ore: Gross weight (dry basis)	Lead ore: Lead content	Lead ore: Zinc content	Zinc ore: Gross weight (dry basis)	Zinc ore: Lead content	Zinc ore: Zinc content	Lead-zinc ore: Gross weight (dry basis)	Lead-zinc ore: Lead content	Lead-zinc ore: Zinc content
Arizona	510	28	(1)	--	--	--	--	--	--
Colorado	(1)	--	--	(1)	--	(1)	163,507	5,707	8,870
Idaho	660	121	19	--	--	--	750,999	24,607	27,500
Missouri	8,262,993	472,054	61,682	--	--	--	--	--	--
Montana	11,688	173	50	--	--	--	(1)	(1)	(1)
Nevada	--	--	--	--	--	--	--	--	--
New Jersey	--	--	--	175,694	--	31,118	--	--	--
New York	--	--	--	144,232	458	12,133	--	--	--
Pennsylvania	--	--	--	477,726	--	21,447	--	--	--
Tennessee	--	--	--	3,256,310	--	81,358	--	--	--
Virginia	--	--	--	445,096	1,596	11,406	--	--	--
Other States[2]	(1)	(1)	(1)	--	--	--	--	--	--
Total	8,275,851	472,376	61,751	4,499,058	2,054	157,462	914,506	30,314	36,370
Percent of total lead-zinc	--	90	23	--	--	59	--	6	14

State	Copper-lead, copper-zinc, and copper-lead-zinc ores: Gross weight (dry basis)	Copper-lead, copper-zinc, and copper-lead-zinc ores: Lead content	Copper-lead, copper-zinc, and copper-lead-zinc ores: Zinc content	All other sources[3]: Gross weight (dry basis)	All other sources[3]: Lead content	All other sources[3]: Zinc content	Total: Gross weight (dry basis)	Total: Lead content	Total: Zinc content
Arizona	--	--	--	[1]47,433,240	[1]326	W	47,433,750	354	W
Colorado	--	--	--	[1]192,336	1,847	[1]1,040	355,843	7,554	9,910
Idaho	--	--	--	703,675	17,908	2,141	1,455,334	42,636	29,660
Missouri	--	--	--	--	--	--	8,262,993	472,054	61,682
Montana	--	--	--	[1]6,402	[1]85	[1]54	18,090	258	104
Nevada	--	--	--	41,188	24	--	41,188	24	--
New Jersey	--	--	--	--	--	--	175,694	--	31,118
New York	--	--	--	--	--	--	144,232	458	12,133
Pennsylvania	--	--	--	--	--	--	477,726	--	21,447
Tennessee	1,900,925	--	3,761	--	--	--	5,157,235	--	85,119
Virginia	--	--	--	--	--	--	445,096	1,596	11,406
Other States[2]	--	--	--	[1]2,060,238	[1]635	[1]4,762	2,060,238	635	4,762
Total	1,900,925	--	3,761	50,437,079	20,825	7,997	66,027,419	525,569	267,341
Percent of total lead-zinc	--	--	1	--	4	3	--	100	100

W Withheld to avoid disclosing company proprietary data; included in "Other States."

[1] Lead ore, zinc ore, lead-zinc ore, and ore from "All other sources" combined to avoid disclosing company proprietary data.

[2] Other States includes California, Illinois, New Mexico, Oregon, Texas, Utah, Washington, and Wisconsin.

[3] Lead and zinc recovered from copper, gold, silver, and fluorspar ores, and from mill tailings and miscellaneous cleanups.

Table 6.—Mine production of recoverable lead in the United States, by month

(Metric tons)

Month	1977	1978	1979
January	40,841	45,233	48,352
February	44,607	40,942	44,673
March	51,594	51,906	43,097
April	48,271	44,916	37,315
May	43,838	49,312	42,046
June	46,133	36,441	42,571
July	38,031	32,257	41,520
August	47,730	43,274	49,403
September	42,114	45,021	35,213
October	44,678	50,370	50,455
November	44,048	45,392	46,776
December	45,614	44,597	44,148
Total	537,499	529,661	525,569

Table 7.—Twenty-five leading lead-producing mines in the United States in 1978, in order of output

Rank	Mine	County and State	Operator	Source of lead
1	Buick	Iron, Mo	AMAX Lead Co. of Missouri	Lead ore.
2	Fletcher	Reynolds, Mo	St. Joe Lead Co	Do.
3	Magmont	Iron, Mo	Cominco American, Inc	Do.
4	Ozark	Reynolds, Mo	Ozark Lead Co	Do.
5	Brushy Creek	do	St. Joe Lead Co	Do.
6	Viburnum No. 29	Washington, Mo	do	Do.
7	Viburnum No. 28	Iron, Mo	do	Do.
8	Lucky Friday	Shoshone, Idaho	Hecla Mining Co	Silver ore.
9	Bunker Hill	do	The Bunker Hill Co	Lead-zinc ore.
10	Star Unit	do	Hecla Mining Co	Lead-zinc and lead ore.
11	Indian Creek	Washington, Mo	St. Joe Lead Co	Lead ore.
12	Leadville Unit	Lake, Colo	ASARCO Incorporated	Lead-zinc ore.
13	Viburnum No. 27	Crawford, Mo	St. Joe Lead Co	Lead ore.
14	Idarado	Ouray and San Miguel, Colo	Idarado Mining Co	Copper-lead-zinc ore.
15	Sunnyside	San Juan, Colo	Standard Metals Corp	Lead-zinc ore.
16	Burgin	Utah, Utah	Kennecott Copper Corp	Do.
17	Bulldog Mountain	Mineral, Colo	Homestake Mining Co	Silver ore.
18	Austinville and Ivanhoe	Wythe, Va	The New Jersey Zinc Co	Zinc ore.
19	Balmat	St. Lawrence, N.Y	St. Joe Lead Co	Do.
20	Tamarack	Shoshone, Idaho	Day Mines, Inc	Lead-zinc ore.
21	Ground Hog	Grant, N. Mex	ASARCO Incorporated	Zinc ore.
22	Pan American	Lincoln, Nev	The Bunker Hill Co	Lead-zinc ore.
23	Sherman Tunnel	Lake, Colo	Leadville Corp.-Day Mines	Silver ore.
24	Ontario	Summit, Utah	Park City Ventures	Lead-zinc ore.
25	Clayton Mine	Custer, Idaho	Clayton Silver Mines	Silver ore.

Table 8.—Twenty-five leading lead-producing mines in the United States in 1979, in order of output

Rank	Mine	County and State	Operator	Source of lead
1	Buick	Iron, Mo	AMAX Lead Co. of Missouri	Lead ore.
2	Fletcher	Reynolds, Mo	St. Joe Lead Co	Do.
3	Magmont	Iron, Mo	Cominco American, Inc	Do.
4	Brushy Creek	Reynolds, Mo	St. Joe Lead Co	Do.
5	Milliken	do	Ozark Lead Co	Do.
6	Viburnum No. 29	Washington, Mo	St. Joe Lead Co	Do.
7	Viburnum No. 28	Iron, Mo	do	Do.
8	Lucky Friday	Shoshone, Idaho	Hecla Mining Co	Silver ore.
9	Bunker Hill	do	The Bunker Hill Co	Lead-Zinc ore.
10	Indian Creek	Washington, Mo	St. Joe Lead Co	Lead ore.
11	Star Unit	Shoshone, Idaho	Hecla Mining Co	Lead-zinc ore.
12	Leadville Unit	Lake, Colo	ASARCO Incorporated	Do.
13	Austinville and Ivanhoe	Wythe, Va	The New Jersey Zinc Co	Zinc ore.
14	Bulldog Mountain	Mineral, Colo	Homestake Mining Co	Silver ore.
15	Sherman Tunnel	Lake, Colo	Leadville Corp.-Day Mines	Do.
16	Galena	Shoshone, Idaho	ASARCO Incorporated	Do.
17	Balmat	St. Lawrence, N.Y	St. Joe Lead Co	Zinc ore.
18	Shullsburg	Lafayette, Wis	Eagle-Picher Industries, Inc	Do.
19	Clayton	Custer, Idaho	Clayton Silver Mines	Silver ore.
20	Sunnyside	San Juan, Colo	Standard Metals Corp	Lead-zinc ore.
21	Minerva No. 1 Mill	Hardin, Ill	Allied Chemical Corp	Fluorspar.
22	Nabob	Shoshone, Idaho	Intermountain Mining Eng., Inc	Lead-zinc ore.
23	Rosiclare	Hardin, Ill	Ozark-Mahonig Co	Fluorspar.
24	Nellie Grant	Lewis and Clark, Mont	Sparrow Resources	Lead ore.
25	Silver Bell Unit	Pima, Ariz	ASARCO Incorporated	Copper ore.

Table 9.—Refined lead produced at primary refineries in the United States, by source material

(Metric tons)

	1975	1976	1977	1978	1979
Refined lead:[1]					
From primary sources:					
Domestic ores and base bullion	481,003	515,767	486,659	501,643	529,970
Foreign ores and base bullion	96,077	76,513	62,041	63,530	45,641
Total	577,080	592,280	548,700	565,173	575,611
From secondary sources	--	26	86	1,244	2,862
Grand total	577,080	592,306	548,786	566,417	578,473
Calculated value of primary refined lead (thousands)[2]	$273,914	$301,628	$371,371	$419,277	$667,372

[1] GSA metal is not included in refined lead production.

[2] Value based on average quoted price and excludes value of refined lead produced from scrap at primary refineries.

Table 10.—Antimonial lead produced at primary lead refineries in the United States

Year	Production (metric tons)	Antimony content		Lead content by difference (metric tons)			
		Metric tons	Percent	From domestic ore	From foreign ore	From scrap	Total
1975	5,469	514	9.4	1,504	424	3,027	4,955
1976	6,117	662	10.8	2,099	2,112	1,244	5,455
1977	6,855	816	11.9	2,459	528	3,052	6,039
1978	5,006	710	14.2	2,384	530	1,382	4,296
1979	3,402	271	8.0	2,491	105	535	3,131

Table 11.—Stocks and consumption of new and old lead scrap in the United States in 1978

(Metric tons, gross weight)

Class of consumer and type of scrap	Stocks Jan. 1	Receipts	Consumption			Stocks Dec.31
			New scrap	Old scrap	Total	
Smelters and refiners:						
Soft lead	4,540	51,553	--	53,551	53,551	2,542
Hard lead	1,226	32,054	--	31,907	31,907	1,373
Cable lead	2,240	42,751	--	43,052	43,052	1,939
Battery-lead plates	58,321	711,687	--	710,350	710,350	59,658
Mixed common babbitt	299	5,339	--	5,214	5,214	424
Solder and tinny lead	273	13,909	--	13,846	13,846	336
Type metals	2,783	25,985	--	25,769	25,769	2,999
Drosses and residues	32,368	172,690	174,187	--	174,187	30,871
Total	102,050	1,055,968	174,187	883,689	1,057,876	100,142
Foundries and other manufacturers:						
Soft lead	--	--	--	--	--	--
Hard lead	--	--	--	--	--	--
Cable lead	--	--	--	--	--	--
Battery-lead plates	--	--	--	--	--	--
Mixed common babbitt	38	4,468	--	4,425	4,425	81
Solder and tinny lead	--	--	--	--	--	--
Type metals	--	--	--	--	--	--
Drosses and residues	--	--	--	--	--	--
Total	38	4,468	--	4,425	4,425	81
All consumers:						
Soft lead	4,540	51,553	--	53,551	53,551	2,542
Hard lead	1,226	32,054	--	31,907	31,907	1,373
Cable lead	2,240	42,751	--	43,052	43,052	1,939
Battery-lead plates	58,321	711,687	--	710,350	710,350	59,658
Mixed common babbitt	337	9,807	--	9,639	9,639	505
Solder and tinny lead	273	13,909	--	13,846	13,846	336
Type metals	2,783	25,985	--	25,769	25,769	2,999
Drosses and residues	32,368	172,690	174,187	--	174,187	30,871
Grand total	102,088	1,060,436	174,187	888,114	1,062,301	100,223

Table 12.—Stocks and consumption of new and old lead scrap in the United States in 1979

(Metric tons, gross weight)

Class of consumer and type of scrap	Stocks Jan. 1	Receipts	Consumption			Stocks Dec. 31
			New scrap	Old scrap	Total	
Smelters and refiners:						
Soft lead	2,542	45,459	--	46,667	46,667	1,334
Hard lead	1,373	25,254	--	25,293	25,293	1,334
Cable lead	1,939	62,462	--	59,601	59,601	4,800
Battery-lead plates	59,658	732,398	--	749,675	749,675	42,381
Mixed common babbitt	424	5,964	--	6,134	6,134	254
Solder and tinny lead	336	14,366	--	13,387	13,387	1,315
Type metals	2,999	16,316	--	16,787	16,787	2,528
Drosses and residues	30,871	172,310	183,036	--	183,036	20,145
Total	100,142	1,074,529	183,036	917,544	1,100,580	74,091
Foundries and other manufacturers:						
Soft lead	--	--	--	--	--	--
Hard lead	--	--	--	--	--	--
Cable lead	--	--	--	--	--	--
Battery-lead plates	--	--	--	--	--	--
Mixed common babbitt	81	4,513	--	4,550	4,550	44
Solder and tinny lead	--	--	--	--	--	--
Type metals	--	--	--	--	--	--
Drosses and residues	--	--	--	--	--	--
Total	81	4,513	--	4,550	4,550	44
All consumers:						
Soft lead	2,542	45,459	--	46,667	46,667	1,334
Hard lead	1,373	25,254	--	25,293	25,293	1,334
Cable lead	1,939	62,462	--	59,601	59,601	4,800
Battery-lead plates	59,658	732,398	--	749,675	749,675	42,381
Mixed common babbitt	505	10,477	--	10,684	10,684	298
Solder and tinny lead	336	14,366	--	13,387	13,387	1,315
Type metals	2,999	16,316	--	16,787	16,787	2,528
Drosses and residues	30,871	172,310	183,036	--	183,036	20,145
Grand total	100,223	1,079,042	183,036	922,094	1,105,130	74,135

Table 13.—Secondary metal recovered[1] from lead and tin scrap in the United States in 1978, by type of product

(Metric tons)

	Lead	Tin	Antimony	Other	Total
Refined pig lead	210,356	--	--	--	210,356
Remelt lead	72,228	--	--	--	72,228
Total	282,584	--	--	--	282,584
Refined pig tin	--	1,565	--	--	1,565
Remelt tin	--	29	--	--	29
Total	--	1,594	--	--	1,594
Lead and tin alloys:					
Antimonial lead	409,910	712	19,614	862	431,098
Common babbitt	6,461	348	672	11	7,492
Genuine babbitt	9	172	16	4	201
Solder	31,408	4,363	1,034	22	36,827
Type metals	16,861	1,038	2,617	1	20,517
Cable lead	3,924	--	31	--	3,955
Miscellaneous alloys	543	81	16	--	640
Total	469,116	6,714	24,000	900	500,730
Tin content of chemical products	--	463	--	--	463
Grand total	751,700	8,771	24,000	900	785,371

[1] Most of the figures herein represent actual reported recovery of metal from scrap.

Table 14.—Secondary metal recovered[1] from lead and tin scrap in the United States in 1979, by type of product

(Metric tons)

	Lead	Tin	Antimony	Other	Total
Refined pig lead	268,647	--	--	--	268,647
Remelt lead	83,574	--	--	--	83,574
Total	352,221	--	--	--	352,221
Refined pig tin	--	1,762	--	--	1,762
Remelt tin	--	20	--	--	20
Total	--	1,782	--	--	1,782
Lead and tin alloys:					
Antimonial lead	378,830	867	18,477	613	398,787
Common babbitt	6,071	328	633	10	7,042
Genuine babbitt	3	113	11	3	130
Solder	33,653	5,282	1,185	32	40,152
Type metals	8,977	584	1,564	--	11,125
Cable lead	2,477	--	26	--	2,503
Miscellaneous alloys	524	75	17	--	616
Total	430,535	7,249	21,913	658	460,355
Tin content of chemical products	--	433	--	--	433
Grand total	782,756	9,464	21,913	658	814,791

[1] Most of the figures herein represent actual reported recovery of metal from scrap.

Table 15.—Secondary lead recovered in the United States

(Metric tons)

	1975	1976	1977	1978	1979
As metal:					
At primary plants	--	26	86	1,244	2,862
At other plants	246,116	282,117	303,063	281,340	349,359
Total	246,116	282,143	303,149	282,584	352,221
In antimonial lead:					
At primary plants	3,027	1,244	3,052	1,382	535
At other plants	282,845	308,983	380,335	408,528	378,295
Total	285,872	310,227	383,387	409,910	378,830
In other alloys	65,353	66,762	71,056	76,742	70,317
Grand total:					
Quantity	597,341	659,132	757,592	769,236	801,368
Value (thousands)[1]	$283,531	$335,675	$512,753	$570,662	$930,019

[1] Value based on average quoted price of common lead.

Table 16.—Lead recovered from scrap processed in the United States, by kind of scrap and form of recovery

(Metric tons)

	1978	1979
Kind of scrap		
New scrap:		
Lead-base	114,908	123,596
Copper-base	4,617	4,944
Tin-base	211	85
Total	119,736	128,625
Old scrap:		
Battery-lead plates	469,555	495,551
All other lead-base	164,467	160,345
Copper-base	15,476	16,845
Tin-base	2	2
Total	649,500	672,743
Grand total	769,236	801,368
Form of recovery		
As soft lead:		
At primary plants	1,244	2,862
At other plants	281,340	349,359
Total	282,584	352,221
In antimonial lead[1]	409,910	378,830
In other lead alloys	58,681	51,271
In copper-base alloys	18,052	19,043
In tin-base alloys	9	3
Total	486,652	449,147
Grand total	769,236	801,368

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[1] Includes 1,282 tons of lead recovered in antimonial lead from secondary sources at primary plants in 1978 and 585 tons in 1979.

Table 17.—Lead consumption in the United States, by product

(Metric tons)

SIC Code	Product	1978	[1]1979
	Metal products:		
3482	Ammunition - shot and bullets	55,776	53,236
	Bearing metals:		
35	Machinery except electrical	--	905
36	Electrical and electronic equipment	--	79
371	Motor vehicles and equipment	--	3,814
37	Other transportation equipment	--	4,832
	Total bearing metals	9,510	9,630
3351	Brass and bronze - billets and ingots	16,502	18,748
36	Cable covering - power and communication	13,851	16,393
15	Calking lead - building construction	9,909	8,017
	Casting metals:		
36	Electrical machinery and equipment	--	1,121
371	Motor vehicles and equipment	--	2,573
37	Other transportation and equipment	--	14,553
3443	Nuclear radiation shielding	--	4,498
	Total casting metals	3,611	22,745
	Pipes, traps, and other extruded products:		
15	Building construction	--	6,237
3443	Storage tanks, process vessels, etc	--	949
	Total pipes, traps, and other extruded products	10,479	7,186
	Sheet lead:		
15	Building construction	--	14,173
3443	Storage tanks, process vessels, etc	--	6,259
3693	Medical radiation shielding	--	([2])
	Total sheet lead	12,626	20,432
	Solder:		
15	Building construction	--	9,777
341	Metal cans and shipping containers	--	14,485
367	Electronic components and accessories	--	10,344
36	Other electrical machinery and equipment	--	2,711
371	Motor vehicles and equipment	--	16,961
	Total solder	68,390	54,278
	Storage battery grids, post, etc.:		
36911	Storage batteries - SLI automotive	--	350,301
36912	Storage batteries - industrial and traction	--	25,253
	Total storage battery grids, post, etc	412,564	375,554
	Storage battery oxides:		
36911	Storage batteries - SLI automotive	--	418,883
36912	Storage batteries - industrial and traction	--	19,895
	Total storage battery oxides	466,710	438,778
371	Terne metal - motor vehicles and equipment	3,778	4,557
27	Type metal - printing and allied industries	10,795	10,019
34	Other metal products[3]	28,994	12,091
	Total metal products	1,123,495	1,051,664
	Pigments:		
285	Paints	--	26,717
32	Glass and ceramic products	--	48,758
28	Other pigments[4]	91,642	15,315
	Total pigments	91,642	90,790
2911	Chemicals - petroleum refining	178,331	186,945
	Miscellaneous uses	39,276	28,936
	Grand total	1,432,744	1,358,335

[1] In 1979, the Bureau of Mines began reporting consumption on a basis of Standard Industrial Codes (SIC).

[2] Included in storage tanks to avoid disclosing company proprietary data.

[3] Includes lead consumed in foil, collapsible tubes, annealing, galvanizing, plating, and fishing weights.

[4] 1978 totals include white lead, red lead, litharge, color and lead content of leaded zinc oxide. 1979 totals include color and lead content of leaded zinc oxide.

Table 18.—Lead consumption in the United States, by month

(Metric tons)

Month	1978	1979
January	120,172	121,756
February	112,305	116,924
March	124,327	132,956
April	121,176	117,091
May	113,108	121,803
June	117,735	112,047
July	93,309	88,060
August	121,733	110,636
September	121,550	114,304
October	138,657	118,477
November	127,929	108,150
December	120,743	96,131
Total[1]	1,432,744	1,358,335

[1] Includes lead that went directly from scrap to fabricated products and lead contained in leaded zinc oxide and other pigments.

Table 19.—Lead consumption in the United States, by class of product and type of material

(Metric tons)

Product	Soft lead	Lead in antimonial lead	Lead in alloys	Lead in copper-base scrap	Total
			1978		
Metal products	97,644	57,696	54,700	11,885	221,925
Storage batteries	494,296	368,377	16,601	--	879,274
Pigments	91,449	193	--	--	91,642
Chemicals	178,473	--	--	--	178,473
Miscellaneous	12,125	10,003	168	--	22,296
Unclassified	35,458	1,205	2,471	--	39,134
Total	909,445	437,474	73,940	11,885	[1]1,432,744
			1979		
Metal products	108,058	63,827	52,610	12,837	237,332
Storage batteries	468,752	329,217	16,363	--	814,332
Pigment	90,790	--	--	--	90,790
Chemicals	186,945	--	--	--	186,945
Miscellaneous	24,120	3,068	1,748	--	28,936
Total	878,665	396,112	70,721	12,837	[1]1,358,335

[1] Includes lead that went directly from scrap to fabricated products and lead contained in leaded zinc oxide and other pigments.

Table 20.—Lead consumption in the United States in 1978, by State[1]

(Metric tons)

State	Refined soft lead	Lead in antimonial lead	Lead in alloys	Lead in copper-base scrap	Total
California	92,583	40,255	5,054	417	138,309
Colorado	626	271	4	--	901
Connecticut	10,107	10,357	--	1,066	21,530
District of Columbia	64	--	--	--	64
Florida	12,894	9,626	738	--	23,258
Georgia	65,508	30,942	1,653	3	98,106
Illinois	40,275	54,467	8,061	1,425	104,228
Indiana	109,172	28,944	4,961	746	143,823
Kansas	26,481	12,758	72	95	39,406
Kentucky	6,788	11,652	2	--	18,442
Maryland	472	1,182	1,346	7	3,007
Massachusetts	427	355	7	259	1,048
Michigan	13,802	17,545	10,606	37	41,990
Missouri	27,409	12,716	1,300	1,139	42,564
Nebraska	1,433	1,379	1,301	1,301	5,414
New Jersey	77,486	5,841	2,404	380	86,111
New York	26,113	5,828	6,089	222	38,252
Ohio	10,182	4,818	2,925	861	18,786
Pennsylvania	100,415	46,052	17,139	1,348	164,954
Rhode Island	2,887	159	38	--	3,084
Tennessee	4,014	14,833	120	135	19,102
Virginia	366	2,431	401	287	3,485
Washington	8,754	2,221	--	--	10,975
West Virginia	10,309	--	--	--	10,309
Wisconsin	5,145	12,207	45	444	17,841
Alabama and Mississippi	10,638	4,874	2,822	982	19,316
Arkansas and Oklahoma	4,548	4,978	--	--	9,526
Hawaii and Oregon	8,440	8,776	--	--	17,216
Iowa and Minnesota	8,784	21,978	950	--	31,712
Louisiana and Texas	195,612	38,853	2,069	564	237,098
Montana and Idaho	425	--	--	--	425
New Hampshire, Maine, Vermont, Delaware	10,208	15,806	355	162	26,531
North and South Carolina	17,067	15,173	1,759	--	33,999
Utah, Nevada, Arizona	13	197	1,722	--	1,932
Total	909,445	437,474	73,940	11,885	1,432,744

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[1] Includes lead that went directly from scrap to fabricated products and lead contained in leaded zinc oxide and other pigments.

Table 21.—Lead consumption in the United States in 1979, by State[1]

(Metric tons)

State	Refined soft lead	Lead in antimonial lead	Lead in alloys	Lead in copper-base scrap	Total
California	96,447	37,918	4,668	536	139,569
Colorado	566	323	32	--	921
Connecticut	10,352	10,706	--	1,051	22,109
District of Columbia	45	--	--	--	45
Florida	13,472	9,206	161	--	22,839
Georgia	51,586	23,983	2,379	8	77,956
Illinois	84,931	39,780	9,870	1,510	136,091
Indiana	110,243	26,742	5,580	786	143,351
Kansas	25,167	10,488	541	80	36,276
Kentucky	7,901	13,636	2	--	21,539
Maryland	533	1,423	1,075	1	3,032
Massachusetts	797	326	26	292	1,441
Michigan	9,944	12,462	1,372	17	23,795
Missouri	19,602	10,651	1,453	1,126	32,832
Nebraska	1,310	1,579	1,609	1,613	6,111
New Jersey	76,977	3,526	4,120	293	84,916
New York	24,468	4,934	6,536	143	36,081
Ohio	9,571	4,046	2,725	639	16,981
Pennsylvania	91,261	45,523	20,195	1,343	158,322
Rhode Island	3,385	159	37	--	3,581
Tennessee	3,795	15,487	178	181	19,641
Virginia	229	2,784	222	214	3,449
Washington	6,399	2,321	--	--	8,720
West Virginia	2,147	--	--	--	2,147
Wisconsin	5,758	11,669	67	614	18,108
Alabama and Mississippi	10,440	3,929	2,812	1,520	18,701
Arkansas and Oklahoma	4,109	4,146	128	--	8,383
Hawaii and Oregon	8,305	8,506	5	--	16,816
Iowa and Minnesota	8,271	21,228	71	--	29,570
Louisiana and Texas	211,624	35,272	2,025	689	249,610
Montana and Idaho	438	--	--	--	438
New Hampshire, Maine, Vermont, Delaware	8,758	15,253	3	181	24,195
North and South Carolina	19,692	17,965	1,694	--	39,351
Utah, Nevada, Arizona	142	141	1,135	--	1,418
Total	878,665	396,112	70,721	12,837	1,358,335

[1] Includes lead that went directly from scrap to fabricated products and lead contained in leaded zinc oxide and other pigments.

Table 22.—Production and shipments of lead pigments[1] and oxides in the United States

Product	1978				1979			
	Production (metric tons)	Shipments			Production (metric tons)	Shipments		
		Metric tons	Value[2]			Metric tons	Value[2]	
			Total	Average per ton			Total	Average per ton
White lead, dry	1,581	1,534	$1,502,698	$889	1,458	1,506	$2,444,183	$1,472
Red lead	17,800	19,227	17,585,278	830	13,904	18,146	17,055,901	853
Litharge	118,759	102,105	84,807,685	754	95,723	100,970	89,961,690	808
Black oxide	430,448	--	--	--	466,587	--	--	--

[1] Excludes basic lead sulfate: withheld to avoid disclosing company proprietary data.
[2] At plant, exclusive of container.

Table 23.-Lead content of lead and zinc pigments[1] and lead oxides produced by domestic manufacturers, by source

(Metric tons)

Product	1978				1979			
	Lead in pigments produced from—			Total lead in pigments	Lead in pigments produced from—			Total lead in pigments
	Ore		Pig lead		Ore		Pig lead	
	Domestic	Foreign			Domestic	Foreign		
White lead	--	--	1,225	1,225	--	--	1,167	1,167
Red lead	--	--	16,198	16,198	--	--	12,653	12,653
Litharge	--	--	105,796	105,796	--	--	89,022	89,022
Black oxide	--	--	417,996	417,996	--	--	443,500	443,500
Total	--	--	541,215	541,215	--	--	546,342	546,342

[1] Excludes lead in basic lead sulfate and leaded zinc oxide; withheld to avoid disclosing company proprietary data.

Table 24.—Distribution of red lead shipments, by industry

(Metric tons)

Industry	1975	1976	1977	1978	1979
Paints	4,130	6,415	5,914	5,993	5,300
Ceramics	W	W	W	W	W
Other	9,564	11,090	11,870	13,234	12,846
Total	13,694	17,505	17,784	19,227	18,146

W Withheld to avoid disclosing company proprietary data; included with "Other."

Table 25.—Distribution of litharge shipments, by industry

(Metric tons)

Industry	1975	1976	1977	1978	1979
Ceramics	30,791	29,302	27,161	33,865	37,620
Insecticides	W	--	--	--	--
Oil refining	W	W	W	W	W
Paints	2,946	7,579	2,455	3,200	3,038
Rubber	5,307	3,465	2,868	2,153	1,520
Other	70,249	70,750	78,789	62,887	58,792
Total	109,293	111,096	111,273	102,105	100,970

W Withheld to avoid disclosing company proprietary data; included with "Other."

Table 26.—U.S. imports for consumption of lead pigments and compounds

Kind	1978		1979	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
White lead	244	$306	112	$346
Red lead	1,550	1,153	1,356	1,664
Litharge	19,478	13,468	16,524	18,673
Chrome yellow	1,140	1,707	1,241	2,915
Other lead pigments	35	58	15	100
Other lead compounds	597	600	470	679
Total	23,044	17,292	19,718	24,377

Table 27.—Stocks of lead at primary smelters and refineries in the United States, Dec. 31

(Metric tons)

Stocks	1975	1976	1977	1978	1979
Refined pig lead	69,593	36,169	12,044	17,001	45,448
Lead in antimonial lead	4,137	3,490	1,945	556	646
Lead base bullion	6,122	6,066	5,312	5,818	5,683
Lead in ore and matte	62,150	64,681	71,812	75,290	37,545
Total	142,002	110,406	91,113	98,665	89,322

Table 28.—Stocks of lead at consumers and secondary smelters in the United States, Dec. 31, by type of material

(Metric tons, lead content)

Year	Refined soft lead	Lead in antimonial lead	Lead in alloys	Lead in copper-base scrap	Total
1975	77,210	37,711	4,589	1,431	120,941
1976	79,627	30,941	5,443	1,569	117,580
1977	74,004	39,247	6,669	1,467	121,387
1978	72,065	44,417	7,564	1,188	125,234
1979	95,655	49,188	7,346	1,006	153,195

Table 29.—Average monthly and annual quoted prices of lead[1]

(Cents per pound)

Month	1978		1979	
	U.S. producer	London Metal Exchange	U.S. producer	London Metal Exchange
January	33.00	30.03	40.76	44.97
February	33.00	26.42	43.63	47.79
March	33.00	26.35	45.75	53.32
April	33.00	25.96	48.00	52.60
May	31.00	24.65	48.81	56.16
June	31.00	25.84	56.51	62.63
July	31.00	26.39	58.07	57.64
August	32.17	28.96	57.91	54.96
September	34.06	31.41	58.00	55.77
October	36.61	37.63	61.06	59.77
November	38.00	36.47	57.26	55.49
December	38.00	38.93	55.95	53.33
Average	33.65	29.86	52.64	54.52

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[1] Metals Week. Quotations for United States on a nationwide, delivered basis.

Table 30.—U.S. exports of lead, by country

Destination	1978 Quantity (metric tons)	1978 Value (thousands)	1979 Quantity (metric tons)	1979 Value (thousands)
Ore and concentrates:				
Belgium-Luxembourg	279	$276	79	$39
Brazil	43,806	5,194	13,280	7,906
Canada	2,361	786	1,578	1,868
Italy	--	--	993	1,083
Japan	34	29	--	--
Korea, Republic of	79	20	--	--
Mexico	2,531	484	5,704	1,598
United Kingdom	48	78	36	53
U.S.S.R	5,068	3,027	11,178	7,035
Venezuela	--	--	30	67
Other	23	22	24	26
Total	54,231	9,916	32,902	19,677
Unwrought lead and lead alloys:				
Argentina	2	5	299	437
Australia	68	68	7	23
Austria	24	21	--	--
Bahamas	8	11	--	--
Belgium-Luxembourg	72	67	194	412
Brazil	54	24	6	18
Canada	1,372	909	978	1,233
Colombia	33	37	1	3
Costa Rica	7	12	6	17
Denmark	110	90	(1)	1
Dominican Republic	18	18	2	3
Ecuador	12	29	27	64
Egypt	--	--	43	159
El Salvador	7	14	10	30
France	23	25	20	34
Germany, Federal Republic of	26	29	102	140
Guatemala	9	34	(1)	2
Haiti	19	26	18	19
Honduras	26	29	55	81
Indonesia	5	38	--	--
Iran	12	32	--	--
Israel	63	64	(1)	9
Italy	25	30	19	19
Japan	45	86	416	461
Korea, Republic of	137	100	163	220
Mexico	217	178	117	367
Netherlands	27	17	764	648
Netherlands Antilles	24	13	47	58
New Zealand	19	17	--	--
Nicaragua	4	6	--	--
Norway	18	13	15	22
Panama	9	9	8	20
Peru	--	--	71	157
Philippines	75	66	53	67
Saudi Arabia	39	59	75	132
Singapore	30	30	(1)	1
South Africa, Republic of	7	3	--	--
Spain	5	17	156	211
Taiwan	20	32	388	402
Thailand	64	50	43	43
Trinidad and Tobago	42	65	(1)	2
United Kingdom	235	340	66	179
U.S.S.R	--	--	3,049	3,857
Venezuela	128	198	21	55
Other	27	37	151	248
Total	3,167	2,948	7,380	9,849
Wrought lead and lead alloys:				
Algeria	9	49	2	34
Argentina	3	15	(1)	1
Australia	3	6	3	16
Austria	(1)	6	--	--
Bahamas	6	7	(1)	2
Belgium-Luxembourg	1,683	587	1,372	579
Brazil	17	11	726	192
Canada	1,906	1,842	191	319
Chile	22	30	27	38
Colombia	17	26	25	34
Costa Rica	8	114	2	6
Dominican Republic	7	27	8	29
Ecuador	51	77	56	106
El Salvador	5	11	5	17
Finland	10	16	11	19
France	15	67	3	6
Germany, Federal Republic of	60	38	1	6
Guatemala	20	28	3	12

See footnote at end of table.

Table 30.—U.S. exports of lead, by country —Continued

Destination	1978 Quantity (metric tons)	1978 Value (thousands)	1979 Quantity (metric tons)	1979 Value (thousands)
Wrought lead and lead alloys —Continued				
Honduras	7	20	11	29
Hong Kong	2	5	3	9
Indonesia	12	50	3	15
Iran	5	44	7	44
Ireland	16	66	1	2
Israel	12	36	4	21
Italy	76	100	56	64
Japan	77	161	95	177
Jordan	11	33	(1)	2
Korea, Republic of	44	44	3	8
Mexico	603	1,690	215	966
Netherlands	6	31	6	64
Netherlands Antilles	3	10	1	6
Norway	1	1	--	--
Panama	47	122	24	89
Philippines	7	21	55	130
Poland	3	74	--	--
Saudi Arabia	113	179	19	59
Singapore	20	46	21	38
South Africa, Republic of	10	14	1	4
Spain	1	5	52	127
Sweden	8	14	10	18
Switzerland	3	13	(1)	2
Taiwan	134	117	46	155
United Arab Emirates	110	62	1	3
United Kingdom	87	162	93	311
Venezuela	80	166	29	77
Other	21	79	75	244
Total	5,058	6,322	3,266	4,080
Scrap:				
Argentina	--	--	684	434
Austria	--	--	33	44
Belgium-Luxembourg	407	318	6,702	3,052
Brazil	6,470	2,128	7,016	5,369
Canada	27,772	7,114	34,019	13,994
Colombia	17	5	--	--
Denmark	1,732	594	1,819	814
El Salvador	14	45	--	--
France	19	30	--	--
Germany, Federal Republic of	9,835	2,451	4,157	1,927
Hong Kong	59	16	--	--
India	18	17	--	--
Italy	36	16	112	96
Japan	4,401	1,204	6,807	1,817
Korea, Republic of	15,249	3,227	14,428	5,608
Mexico	10,624	1,767	9,352	1,852
Netherlands	3,301	1,737	503	690
Philippines	59	16	194	56
South Africa, Republic of	3,546	1,111	10,752	6,186
South-West Africa, Territory of (Namibia)	--	--	1,612	1,141
Spain	2,163	870	36	37
Sweden	86	50	16[illegible]	120
Taiwan	8,764	2,113	16,116	6,257
United Kingdom	2,040	2,218	3,122	2,965
Venezuela	1,337	419	1,579	915
Yugoslavia	637	165	498	129
Other	47	23	47	41
Total	98,633	27,654	119,748	53,514
Grand total	161,089	46,840	163,296	87,120

[1] Less than 1/2 unit.

Table 31.—U.S. exports of lead, by class

Year	Blocks, pigs, anodes, etc.				Wrought lead and lead alloys				Scrap	
	Unwrought		Unwrought alloys		Sheets, plates, rods, other forms		Foil, powder, flakes			
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1977	1,887	$1,243	2,414	$2,002	4,297	$4,325	283	$845	77,484	$22,442
1978	2,145	1,643	1,022	1,305	4,787	6,027	271	295	98,633	27,654
1979	6,585	8,383	795	1,496	2,349	3,456	917	624	119,748	53,514

Table 32.—U.S. imports[1] of lead, by country

Country	1977		1978		1979	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Ore, flue dust, and residues, n.s.p.f. (lead content):						
Argentina	--	--	161	$130	152	$160
Australia	16,592	$8,894	6,522	3,823	1,923	1,828
Bolivia	818	147	1,218	227	--	--
Canada	16,080	7,400	19,587	8,467	12,762	10,954
Colombia	132	71	86	57	136	145
Honduras	23,740	13,813	13,424	8,899	10,923	11,619
Mexico	1,040	206	4,578	1,426	1,646	1,606
Netherlands	--	--	335	131	--	--
Nicaragua	1,584	972	725	474	12	10
Peru	6,597	3,158	6,347	3,042	12,444	11,287
Other	--	--	2	1	--	--
Total	66,533	34,661	52,985	26,677	39,998	37,609
Base bullion (lead content):						
Belgium-Luxembourg	100	62	40	29	(2)	1
Canada	448	291	3,993	2,705	1,654	1,654
Denmark	--	--	14	11	27	36
Mexico	4,304	2,368	260	185	--	--
Morocco	996	561	--	--	--	--
Peru	100	70	--	--	--	--
South-West Africa, Territory of (Namibia)	1,367	869	--	--	--	--
Other	4	23	--	--	--	--
Total	7,319	4,244	4,307	2,930	1,681	1,691
Pigs and bars (lead content):						
Australia	19,859	12,540	16,327	10,575	17,275	18,597
Belgium-Luxembourg	6,908	5,006	7,479	11,424	1,981	11,026
Burma	152	79	--	--	--	--
Canada	75,436	51,749	70,378	53,224	71,342	79,512
Denmark	175	221	658	588	521	726
France	978	544	1,500	865	2,000	2,041
Germany, Federal Republic of	18,728	12,495	8,458	9,481	574	5,529
Japan	317	271	(2)	1	4	12
Mexico	71,779	44,182	80,213	54,818	73,643	76,488
Morocco	--	--	6,007	3,916	--	--
Netherlands	100	54	514	371	--	--
Poland	--	--	101	57	--	--
Peru	30,432	18,674	25,725	17,004	17,903	19,387
South Africa, Republic of	2,361	1,273	--	--	1,299	1,260
South-West Africa, Territory of (Namibia)	--	--	--	--	3,913	4,231
Spain	--	--	1,000	636	--	--
Sweden	--	--	1,007	605	--	--
Thailand	249	1,397	181	963	--	--
United Kingdom	2,586	2,444	1,724	1,963	801	1,979
Yugoslavia	6,889	3,576	--	--	--	--
Other	74	39	41	21	406	523
Total	237,023	154,544	221,313	166,512	191,662	221,311
Reclaimed scrap, etc. (lead content):						
Australia	2,663	1,294	2,306	1,769	2,676	2,349
Bahamas	15	3	19	17	18	3
Barbados	--	--	37	31	3	2
Canada	2,238	1,226	2,747	1,761	2,661	2,720
Dominican Republic	1	2	27	12	56	39
Germany, Federal Republic of	996	569	--	--	--	--
Guatemala	--	--	--	--	102	62
Haiti	5	4	6	14	5	12
Jamaica	45	7	12	4	48	7
Mexico	124	69	366	134	896	652
Netherlands Antilles	44	25	2	(2)	9	8
Panama	--	--	35	58	19	16
Spain	--	--	--	--	36	157
United Kingdom	--	--	27	44	17	16
Other	10	13	29	12	136	86
Total	6,141	3,212	5,613	3,856	6,682	6,129
Grand total	317,016	196,661	284,218	199,975	240,023	266,740

[1] Data are "general imports;" that is, they include lead imported for immediate consumption plus material entering the country under bond.

[2] Less than 1/2 unit.

Table 33.—U.S. imports for consumption of lead, by country

Country	1977		1978		1979	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Ore, flue dust, and residues, n.s.p.f. (lead content):						
Argentina	--	--	161	$130	152	$160
Australia	13,264	$5,508	8,542	2,653	5,780	1,831
Bolivia	818	422	1,218	226	--	--
Canada	8,701	2,812	13,502	4,156	7,866	4,822
Colombia	278	126	86	57	136	145
Denmark	--	--	1,304	273	--	--
Honduras	37,918	18,408	15,912	10,050	15,048	12,814
Mexico	5,400	2,273	4,578	1,426	1,646	1,606
Nicaragua	4,761	2,529	571	413	12	10
Peru	17,639	7,734	16,062	5,885	13,761	11,638
Other	--	--	2	1	--	--
Total	88,779	39,812	61,938	25,220	44,401	33,026
Base bullion (lead content):						
Belgium-Luxembourg	100	62	40	29	(1)	1
Canada	448	291	3,993	2,705	1,654	1,654
Denmark	--	--	14	11	27	36
Germany, Federal Republic of	4	23	--	--	--	--
Mexico	4,304	2,368	260	185	--	--
Morocco	996	561	--	--	--	--
Peru	100	70	--	--	--	--
South-West Africa, Territory of (Namibia)	1,367	869	--	--	--	--
Total	7,319	4,244	4,307	2,930	1,681	1,691
Pigs and bars (lead content):						
Argentina	--	--	37	18	--	--
Australia	12,906	7,414	20,419	13,929	8,163	6,737
Belgium-Luxembourg	6,908	5,006	7,479	11,424	1,981	11,026
Canada	75,436	51,749	70,378	58,224	71,342	79,512
Denmark	175	221	658	588	521	726
France	978	544	1,500	865	2,000	2,041
Germany, Federal Republic of	18,728	12,495	8,458	9,481	574	5,529
Japan	317	271	1	1	4	12
Mexico	71,779	44,183	80,213	54,818	73,643	76,488
Morocco	--	--	6,007	3,916	--	--
Netherlands	100	54	514	371	--	--
Peru	30,432	18,674	25,725	17,004	17,903	19,387
Poland	--	--	101	57	--	--
South Africa, Republic of	2,361	1,273	--	--	1,299	1,260
South-West Africa, Territory of (Namibia)	--	--	--	--	3,913	4,231
Spain	--	--	1,000	636	--	--
Sweden	--	--	1,007	605	--	--
Thailand	249	1,397	181	963	--	--
United Kingdom	2,585	2,444	1,724	1,963	801	1,979
Yugoslavia	6,889	3,576	--	--	--	--
Other	226	118	4	3	406	523
Total	230,069	149,419	225,406	169,866	182,550	209,451
Reclaimed scrap, etc. (lead content):						
Australia	45	17	--	--	(1)	2
Bahamas	15	3	19	17	18	3
Canada	2,238	1,226	2,748	2,555	2,661	2,720
Dominican Republic	1	2	27	12	56	39
Germany, Federal Republic of	996	569	--	--	--	--
Guatemala	--	--	--	--	102	62
Jamaica	44	7	12	4	48	7
Mexico	124	69	366	132	896	652
Netherlands Antilles	44	25	2	(1)	9	8
Panama	2	6	34	58	19	16
Spain	--	--	--	--	36	157
United Kingdom	--	--	27	44	17	16
Other	14	11	72	56	144	100
Total	3,523	1,935	3,307	2,878	4,006	3,782

See footnote at end of table.

Table 33.—U.S. imports for consumption of lead, by country —Continued

Country	1977 Quantity (metric tons)	1977 Value (thousands)	1978 Quantity (metric tons)	1978 Value (thousands)	1979 Quantity (metric tons)	1979 Value (thousands)
Sheets, pipe, shot:						
Belgium-Luxembourg	([1])	$1	([1])	$1	([1])	$1
Canada	613	465	1,027	946	201	305
Denmark	52	232	1	1	--	--
France	--	--	([1])	([1])	1	1
Germany, Federal Republic of	43	50	42	62	1	8
Japan	5	13	1	2	([1])	([1])
Mexico	20	18	--	--	--	--
Spain	135	636	366	1,100	--	--
Taiwan	--	--	([1])	([1])	9	9
United Kingdom	21	100	1	4	3	4
Other	([1])	1	--	--	([1])	([1])
Total	889	1,516	1,438	2,116	215	328
Grand total	330,579	196,926	296,396	203,010	282,853	248,278

[1] Less than 1/2 unit.

Table 34.—U.S. imports for consumption of lead, by class

(Thousand short tons and thousand dollars)

Year	Ore (lead content)		Base bullion (lead content)		Pigs and bars (lead content)		Sheets, plates, strip, other forms	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1977	89	39,812	7	4,244	230	149,419	1	1,516
1978	62	25,220	4	2,930	225	169,866	1	2,116
1979	44	33,026	2	1,691	183	209,451	([1])	328

Year	Waste and scrap (lead content)		Dross, skimmings, residues, n.s.p.f. (lead content)		Powder and flakes		Total value
	Quantity	Value	Quantity	Value	Quantity	Value	
1977	3	1,769	([1])	166	([1])	183	197,109
1978	3	2,086	1	806	([1])	64	203,088
1979	4	3,207	([1])	575	([1])	288	248,566

[1] Less than 1/2 unit.

Table 35.—U.S. imports for consumption of miscellaneous products containing lead[1]

Year	Gross weight (metric tons)	Lead content (metric tons)	Value (thousands)
1977	602	257	$3,586
1978	560	262	3,683
1979	362	107	3,565

[1] Babbitt metal, solder, white metal, and other lead-containing combinations.

Table 36.—Lead: World mine production, by country

(Thousand metric tons)

Continent and country[1]	1976	1977	1978[p]	1979[e]
North America:				
Canada	256.3	281.0	319.8	[3]315.8
Guatemala	[e].1	.1	[e] [3].1	.1
Honduras	18.6	23.5	21.8	10.0
Mexico[4]	200.0	163.5	170.5	180.0
Nicaragua	1.3	1.0	.4	--
United States[5]	553.0	537.5	529.7	[3]525.6
South America:				
Argentina	[r]33.0	33.6	29.9	31.0
Bolivia	16.4	19.3	18.0	[3]15.4
Brazil	22.6	24.0	24.0	24.0
Chile	1.8	.9	.5	1.0
Colombia	.1	.1	[e].1	.1
Ecuador	[r].2	.2	.2	.2
Peru[6]	159.8	166.1	182.7	[3]184.8
Europe:				
Austria	4.4	4.3	4.6	5.0
Bulgaria	[r]110.0	117.0	[e]117.0	117.0
Czechoslovakia	4.2	4.3	4.0	4.0
Finland	1.1	.6	.8	1.0
France	[r]28.0	31.5	32.5	[3]29.3
German Democratic Republic	4.0	--	--	--
Germany, Federal Republic of	31.7	31.1	23.2	38.0
Greece	[r]28.2	16.4	20.3	20.0
Greenland	27.0	28.8	30.6	31.0
Hungary	.9	1.3	1.0	1.1
Ireland	32.6	41.0	47.8	70.0
Italy	[r]29.4	31.5	30.5	30.0
Norway	3.9	3.3	3.6	3.0
Poland	60.0	63.0	63.9	65.0
Romania	[r] [e]35.0	[r] [e]35.0	33.3	33.3
Spain	62.2	61.0	72.4	72.0
Sweden	81.6	88.1	81.9	[3]84.4
U.S.S.R.[e]	500.0	510.0	520.0	525.0
United Kingdom	7.1	7.6	4.6	[3]2.0
Yugoslavia	122.5	130.0	124.5	[3]128.3
Africa:				
Algeria	2.1	.9	1.8	2.1
Congo (Brazzaville)	[r]2.5	2.4	4.2	8.0
Kenya[e]	[r].5	--	--	--
Morocco	60.2	93.4	100.2	110.0
Nigeria	.1	.1	.1	.1
South-West Africa, Territory of (Namibia)	46.4	41.2	38.6	40.4
Tunisia	10.4	10.2	8.0	8.0
Zambia	[r]15.5	13.5	13.0	13.0
Asia:				
Burma	[r]7.1	8.9	7.2	11.0
China, mainland[e]	[r]90.0	100.0	120.0	120.0
India	[r]12.1	12.7	[e]16.2	13.0
Iran	[r]35.0	[r]40.0	[e]30.0	28.0
Japan[7]	51.7	54.8	56.9	[3]47.4
Korea, North[e]	110.0	110.0	105.0	105.0
Korea, Republic of	14.5	16.6	16.1	13.0
Philippines	4.5	3.7	1.7	2.0
Thailand	.9	.5	1.7	[3]8.7
Turkey	4.9	8.7	9.5	20.0
Oceania: Australia[8]	[r]397.4	432.2	400.3	[3]415.6
Total	[r]3,302.8	3,406.4	3,444.7	3,512.7

[e]Estimate. [p]Preliminary. [r]Revised.

[1] In addition to the countries listed, Egypt and Uganda may produce lead, but available information is inadequate to make reliable estimates of output levels.

[2] Reported figure.

[3] Smelter production; believed to closely approximate mine output, which is unreported.

[4] Recoverable metal content of lead in concentrates for export plus lead content of domestic smelter products (refined lead, antimonial lead, mixed bars, and other unspecified items).

[5] Recoverable.

[6] Recoverable metal content of lead in concentrates for export plus lead content of domestic smelter products (refined lead, antimonial lead, and bismuth-lead bars).

[7] Content of concentrates.

[8] Content by analysis.

Table 37.—Lead: World primary and secondary smelter production, by country[1]

(Thousand metric tons)

Country	1976	1977	1978[p]	1979[e]
North America:				
Canada:				
Primary (refined)	175.7	187.5	194.1	187.1
Secondary	[r]55.3	53.1	60.0	55.0
Total	[r]231.0	240.6	254.1	[2]242.1
Guatemala, primary	.1	.1	.1	.1
Mexico:				
Primary[3]	189.7	153.9	166.1	160.0
Secondary	[r]45.0	62.3	49.3	49.0
Total	[r]234.7	216.2	215.4	209.0
United States:				
Primary (refined)	592.3	548.7	565.2	[2]575.6
Secondary	659.1	757.6	769.2	[2]801.4
Total	1,251.4	1,306.3	1,334.4	[2]1,377.0
South America:				
Argentina:				
Primary	[r]50.0	45.0	31.3	35.0
Secondary	[r]6.0	6.0	6.0	6.0
Total	[r]56.0	51.0	37.3	41.0
Brazil:				
Primary	43.7	48.3	49.0	50.0
Secondary	[r]28.5	30.0	31.6	31.0
Total	[r]72.2	78.3	80.6	81.0
Peru, primary (refined)[4]	[r]74.1	79.4	74.3	[2]85.7
Venezuela, secondary only	[r]7.0	8.0	9.0	10.0
Europe:				
Austria:				
Primary	[r]6.3	6.3	5.8	7.5
Secondary	[r]9.9	10.5	9.3	8.5
Total	[r]16.2	16.8	15.1	16.0
Belgium:				
Primary[e]	[r]106.0	104.0	104.2	91.8
Secondary[e]	[r]15.5	18.8	20.8	24.3
Total	[r]121.5	122.8	125.0	116.1
Bulgaria, primary and secondary	[r]112.0	120.0	120.0	120.0
Czechoslovakia, primary and secondary	19.1	19.0	19.0	19.1
France:				
Primary	[r]118.4	127.0	125.9	[2]127.0
Secondary	[r]70.3	75.2	82.3	[2]94.7
Total	[r]188.7	202.2	208.2	[2]221.7
German Democratic Republic:				
Primary[e]	20.0	20.0	20.0	20.0
Secondary[e]	16.0	17.0	18.0	18.0
Total[e]	36.0	37.0	38.0	38.0
Germany, Federal Republic of:				
Primary	101.0	105.1	105.2	138.5
Secondary	177.3	204.5	199.8	203.0
Total	278.3	309.6	305.0	341.5
Greece:				
Primary[e]	16.8	14.5	17.0	[2]15.6
Secondary[e]	1.9	4.2	5.5	6.0
Total	18.7	18.7	22.5	[2]21.6
Hungary, secondary only[e]	[r].3	[r].2	.3	.3

See footnotes at end of table.

Table 37.—Lead: World primary and secondary smelter production, by country[1] —Continued

(Thousand metric tons)

Country	1976	1977	1978[p]	1979[e]
Europe —Continued				
Italy:				
Primary	46.0	34.2	31.1	30.0
Secondary	72.2	83.5	85.1	85.0
Total	118.2	117.7	116.2	115.0
Netherlands:				
Primary	21.9	21.1	18.2	20.0
Secondary	[r]14.8	12.7	13.7	9.6
Total	[r]36.7	33.8	31.9	29.6
Norway, secondary only[e] [5]	.6	.9	.3	.4
Poland,[6] primary and secondary (refined)	80.6	85.4	86.7	84.2
Portugal,[5] primary and secondary	[r].5	.1	.1	.1
Romania, primary and secondary	48.7	53.4	51.9	49.8
Spain:				
Primary	[r]73.2	33.4	82.8	90.0
Secondary	[r]27.1	29.9	41.0	40.0
Total	[r]100.3	113.3	123.8	130.0
Sweden:				
Primary	49.1	51.9	45.3	50.0
Secondary	.3	.1	[e].1	.1
Total	49.4	52.0	45.4	50.1
U.S.S.R.:				
Primary[e]	500.0	510.0	520.0	525.0
Secondary[e]	100.0	100.0	100.0	100.0
Total[e]	600.0	610.0	620.0	625.0
United Kingdom:				
Primary	16.5	35.0	30.4	[2]32.3
Secondary (refined)	[r]209.7	211.4	222.9	[2]244.2
Total	[r]226.2	246.4	253.3	[2]276.5
Yugoslavia:[e]				
Primary[e]	[r]121.2	125.3	[e]121.0	110.0
Secondary[e]	[r]19.2	19.7	[e]19.0	20.0
Total	[r]140.4	145.0	[e]140.0	130.0
Africa:				
Morocco:				
Primary[e]	24.8	31.6	27.0	35.3
Secondary[e]	1.6	1.5	1.5	1.4
Total[7]	26.4	33.1	28.5	[2]36.7
South Africa, Republic of, secondary[5]	22.0	24.0	23.6	22.9
South-West Africa, Territory of (Namibia), primary	[r]39.0	42.7	39.5	[2]41.6
Tunisia:				
Primary[8]	[r]19.7	19.2	16.1	16.0
Secondary	[r].7	.5	.5	.6
Total	[r]20.4	19.7	16.6	16.6
Zambia, primary	13.6	13.1	10.7	11.0
Asia:				
Burma:				
Primary	[r]3.1	4.7	4.9	5.0
Secondary	[r].2	.1	.1	.1
Total[9]	[r]3.3	4.8	5.0	5.1
China:				
Mainland, primary and secondary[e]	100.0	110.0	150.0	150.0
Taiwan, secondary[5]	11.7	11.5	14.5	13.7

See footnotes at end of table.

Table 37.—Lead: World primary and secondary smelter production, by country[1] —Continued

(Thousand metric tons)

Country	1976	1977	1978[p]	1979[e]
Asia —Continued				
India:				
Primary	5.4	7.6	9.2	10.0
Secondary[e] [8]	9.6	12.4	10.9	11.0
Total	15.0	20.0	20.1	21.0
Iran, primary	([10])	([10])	--	--
Japan:				
Primary	[r]158.2	170.0	186.1	[2]180.3
Secondary	60.9	151.4	42.3	[2]41.0
Total	[r]219.1	321.4	228.4	[2]221.3
Korea, North, primary and secondary[e]	70.0	70.0	75.0	75.0
Korea, Republic of, primary and secondary	7.8	6.7	7.2	7.2
Thailand, secondary	.8	1.2	1.1	1.0
Turkey, primary and secondary	3.2	3.0	3.0	3.0
Oceania: Australia:				
Primary:				
Bullion (for export)	160.7	156.4	152.0	[2]160.4
Refined[11]	181.9	181.5	204.0	[2]215.7
Subtotal	[r]342.6	337.9	356.0	[2]376.1
Secondary	[r]29.6	36.5	35.1	[2]39.1
Total	[r]372.2	374.4	391.1	[2]415.2
Grand total	[r]5,043.4	5,339.8	5,342.2	5,472.2
Of which:				
Primary	2,928.4	2,927.5	2,956.5	3,026.5
Secondary	1,673.1	1,944.7	1,872.8	1,937.3
Undifferentiated	441.9	467.6	512.9	508.4

[e] Estimate. [p] Preliminary. [r] Revised.

[1] Table combines data provided in tables 32 and 33, of the 1977 edition of this chapter. Wherever possible, detailed information on raw material source of output (primary—directly from ores and secondary—from scrap) has been provided. In cases where raw material source is unreported and insufficient data are available to estimate the distribution of the total, that total has been left undifferentiated (primary and secondary). To the extent possible, this table reflects metal production at the first measurable state (smelter production) rather than refined production. Thus, production of lead bullion is credited to the country in which it was produced, and refined lead produced from imported bullion is not included to avoid double counting. For some countries, data on actual smelter output are not available but refined lead output is reported, and these data have been included, appropriately noted.

[2] Reported figure.

[3] Lead content of refined lead, antimonial lead, and impure lead bars produced from indigenous ores. Previous editions were incorrectly labeled as including secondary, if any was produced. An additional quantity of secondary lead is produced (see next line in table).

[4] Lead content of refined lead and antimonial lead produced from indigenous ores.

[5] Series added; not included in 1977 edition.

[6] Series revised to reflect smelter output, rather than refined output, which appeared in 1977 edition.

[7] Previously reported as primary only.

[8] Excludes lead content of antimonial lead.

[9] Lead content of smelter lead and antimonial lead produced from indigenous ores, and scrap.

[10] Revised to zero.

[11] Produced from indigenous ores, in addition to lead content of bullion produced from indigenous ores.

Lime

By J. W. Pressler[1]

Lime output in 1978, including that for Puerto Rico, increased 2% to 20.4 million tons, and continued with a 2% increase in 1979 to 21 million tons. Total value established new annual records, increasing 12% in 1978 to $753 million, and 15% in 1979 to $866 million.

In 1978, output of agricultural lime and construction lime decreased 14% and 6%, respectively, while output of chemical and industrial lime and refractory lime increased 3% and 5%, respectively. In 1979, output of agricultural and refractory lime decreased 9% and 22%, respectively, while construction lime and chemical and industrial lime increased 7% and 4%, respectively.

Table 1.—Salient lime statistics in the United States[1]

(Thousand short tons and thousand dollars)

	1975	1976	1977	1978	1979
Number of plants	171	163	161	155	154
Sold or used by producers:					
Quicklime	15,875	16,924	16,281	16,845	17,553
Hydrated lime	2,344	2,298	2,698	2,582	2,599
Dead-burned dolomite	914	1,007	968	1,016	793
Total	19,133	20,229	19,947	20,443	20,945
Value[2]	$523,805	$609,010	$666,472	$749,667	$862,459
Average value per ton	$27.38	$30.11	$33.41	$36.67	$41.18
Lime sold	12,840	14,024	14,202	15,062	15,423
Lime used	6,292	6,205	5,745	5,381	5,522
Exports[3]	54	56	33	45	45
Imports for consumption[3]	259	365	423	610	640

[1] Excludes regenerated lime. Excludes Puerto Rico.
[2] Selling value, f.o.b. plant, excluding cost of containers.
[3] Bureau of the Census.

DOMESTIC PRODUCTION

Lime producers sold or used 21 million tons in 1979, compared with 20 million tons in 1977. Commercial sales of lime increased 6% in 1978 to 15.1 million tons, and 2% in 1979 to 15.5 million tons. Captive lime used by producers continued its long-term decline, with a 6% reduction in 1978 to 5.4 million tons, but increased 3% in 1979 to 5.5 million tons. This was a 24% decrease from the record year of 1971.

For the 2-year period 1978-79, output of quicklime increased 6% to 18.3 million tons. Production of hydrated lime decreased 4% to 2.6 million tons. Output of dead-burned dolomite decreased 18%, 67% below the 1956 record level of 2.4 million tons.

In 1979, six States—Ohio, Pennsylvania, Missouri, Texas, Alabama, and Michigan—accounted for 53% of the total output. Compared with 1977, production increased 11% in Alabama, 7% in Pennsylvania, 6% in Ohio, 4% in Missouri, and decreased 22% in Michigan and 6% in Texas.

Leading producing companies in 1979 were Marblehead Lime Co. with two plants in Illinois and one each in Indiana, Mich-

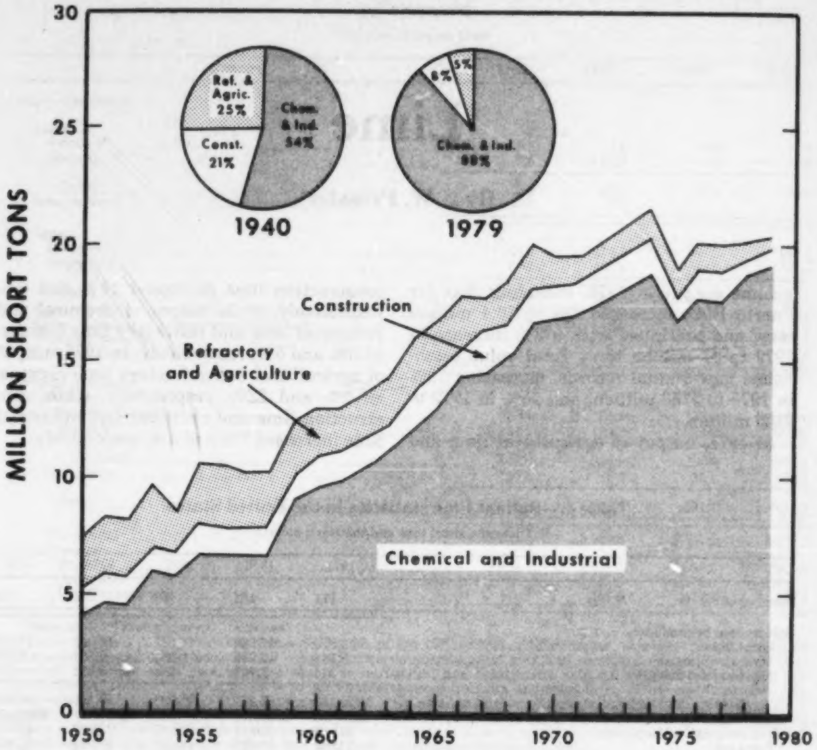

Figure 1.—Trends in major uses of lime.

gan, Pennsylvania, and Utah; Mississippi Lime Co. in Missouri; Dravo Corp. with one plant each in Alabama, Kentucky, Louisiana, and Texas; Bethlehem Steel Corp. with two plants in Pennsylvania and one in New York; Martin Marietta Corp.'s Chemical Div. in Alabama and Ohio; The Flintkote Co. with two plants in California, two in Nevada, and one each in Arizona, Utah, and Virginia; Allied Chemical Corp. in New York; Allied Products Co. with two plants in Alabama; United States Gypsum Co. in Louisiana, Ohio, and Texas; and Pfizer, Inc., in California, Connecticut, Massachusetts, and Ohio. These 10 companies, operating 33 plants, accounted for 47% of the total 1979 lime production.

In 1979, the eight largest lime plants, each producing more than 400,000 tons, accounted for 27% of the total lime output. Thirty-nine plants produced more than 200,000 tons and accounted for 68% of the total.

Leading individual plants in 1979 were Mississippi Lime's Ste. Genevieve plant, Allied Chemical's Syracuse plant, Marblehead's Buffington plant, Dravo's Maysville plant, and Martin Marietta's Woodville plant.

A total of 485 kilns were operational during 1979: 248 vertical kilns, 181 rotary kilns, 27 pot kilns (primitive vertical), 16 Calcimatic traveling-hearth kilns, 6 fluidized-bed kilns, 4 Ellernan kilns, and 1 traveling-grate rotary kiln. Hydrators for the production of hydrate lime totaled 118 during 1979; 23 were of the batch type and 95 were of the continuous type.

In the biennial period of 1978-79, the number of lime plants in the United States decreased from 167 to 155, and the average output per plant increased from 123,400 to 135,400 tons per year.

New Plants and Expansions.—Greer Lime Co., a subsidiary of Greer Steel Co. of Dover, Ohio, purchased Olin Corp.'s Salt-

Table 2.—Lime sold or used by producers in the United States, by State and kind[1]

(Thousand short tons and thousand dollars)

State	1978					1979				
	Plants	Hydrated	Quicklime	Total[2]	Value	Plants	Hydrated	Quicklime	Total[2]	Value
Alabama	5	170	1,094	1,264	49,021	5	147	1,126	1,273	54,182
Arizona	6	--	498	498	19,743	6	--	673	673	27,186
Arkansas	3	W	W	171	5,708	3	W	W	160	6,287
California	13	W	W	522	21,691	13	W	W	563	25,545
Colorado, Nevada, Wyoming	12	96	340	436	18,133	12	94	374	468	20,643
Connecticut	1	13	17	29	1,564	1	13	20	33	2,053
Florida	3	W	W	180	8,182	3	W	W	210	11,440
Hawaii, Idaho, Oregon, Washington	10	24	261	285	11,866	9	33	403	436	20,757
Illinois and Indiana	5	94	2,183	2,278	74,332	5	83	2,004	2,087	73,304
Iowa, Kansas, Nebraska, North Dakota, South Dakota	9	52	248	300	9,787	9	72	281	353	12,445
Kentucky, New York, Tennessee, West Virginia	8	52	1,825	1,877	63,884	9	38	2,163	2,202	87,576
Louisiana, New Mexico, Oklahoma	5	96	338	434	17,554	5	119	330	449	21,392
Maryland	1	5	8	12	436	1	5	7	12	444
Massachusetts	2	17	181	199	8,478	2	17	181	198	9,918
Michigan	9	--	1,291	1,291	45,814	9	--	1,057	1,057	43,373
Minnesota	4	--	116	116	4,263	4	--	140	140	5,133
Mississippi	1	--	49	49	1,108	1	--	70	70	1,571
Missouri	3	362	1,428	1,791	63,642	3	389	1,401	1,790	70,187
Montana	3	--	204	204	7,030	3	--	216	216	8,965
New Jersey	1	17	--	17	787	1	1	--	1	61
Ohio	15	198	3,269	3,467	129,316	14	164	3,229	3,392	141,663
Pennsylvania	10	369	1,757	2,126	83,869	10	414	1,739	2,153	96,569
Puerto Rico	1	39	2	41	3,249	1	35	2	37	3,307
Texas	11	644	764	1,408	48,882	11	656	851	1,507	59,520
Utah	4	W	W	225	7,196	3	W	W	198	8,250
Virginia	6	94	738	832	30,578	7	102	770	872	34,935
Wisconsin	5	130	300	430	17,301	5	120	309	429	19,060
Other[3]	([4])	149	952	([4])	([4])	([4])	131	1,001	([4])	([4])
Total[2]	156	2,621	17,863	20,484	752,915	155	2,634	18,349	20,983	865,766

W Withheld to avoid disclosing company proprietary data; included in "Other."

[1] Excludes regenerated lime. Includes Puerto Rico.

[2] Data may not add to totals shown because of independent rounding.

[3] Includes States indicated by symbol W and exports.

[4] Included with data for each individual State.

ville, Va., dormant lime kiln in 1978. After rehabilitation and operation since September 1979, Greer Lime's annual quicklime capacity was indicated as 60,000 tons.

Marblehead Lime Co., a subsidiary of General Dynamics Corp., continued its position as the largest U.S. producer. It further strengthened its position by initiating construction and installation in 1978 of a 600,000-ton-per-year rotary kiln at its South Chicago plant, including the retirement of 140,000 tons per year of obsolete capacity. This will be the largest lime kiln in the world when placed onstream in 1980. The Thornton, Ill., plant will expand its present capacity by 250,000 tons per year with a new kiln and auxiliary equipment. Two additional Marblehead expansion projects with a total outlay of $25 million were started in 1979, the first at the River Rouge plant in Detroit, Mich., and the second in Tooele, Utah. The Tooele plant's capacity to produce refractory-grade, dead-burned dolomite was expanded by 50% to 150,000 tons per year by yearend 1979.[2]

The Sierra Chemical Co. of Reno, Nev., started production of lime at Caselton, Nev., in Lincoln County, using limestone from a deposit located 8 miles south of Caselton. Reported capacity is 100 tons per day of quicklime.

Rosario Resources Corp. sold its Dixie Lime & Stone Co.'s Sumterville, Fla., lime plant in 1979 to Amcar Inc., an American subsidiary of S. A. Carmeuse of Seilles, Belgium, for $9 million.[3]

Calco, Inc., of Salida, Colo., installed a 6-1/2-foot-diameter by 120-foot-long rotary kiln in 1979, with a quicklime capacity of 100 tons per day. Direct-fired by a Herbert attrition coal pulverizer-dryer, the high-calcium quicklime will be marketed for chemical and industrial uses. Limestone raw material is trucked from Monarch Pass to Salida.[4]

Steel Bros. Canada, Ltd., of Vancouver, British Columbia, initiated construction of a $7 million, 500-ton-per-day quicklime plant in 1979 south of Delta, Utah, in Millard County, with completion scheduled for 1980. The production will be marketed in the chemical and industrial industry, with major uses in the flue gas desulfurization of powerplants.[5]

Southern Industries Corp. of Mobile, Ala., acquired the Round Rock Lime Co.'s plant in Blum, Tex., in 1979, with a capacity of over 200,000 tons per year of quicklime. Southern also owns the S. I. Lime Co.'s Saginaw plant in Shelby County, Ala. Soon after Round Rock's acquisition, the Alabama-based firm was merged into Dravo Corp. of Pittsburgh, Pa., in a stock exchange of $60 million. This moved Dravo into the third ranking position in the United States, with total shipments approaching 1.4 million tons per year of lime.[6]

Domtar Chemicals Group, Lime Div., of Montreal, Quebec, Canada, announced in late 1979 a $3.5 million expansion and modernization program for its Bellefonte, Pa., lime plant. Kiln improvements, with addition of pollution control equipment and mine rehabilitation, will be involved.[7]

Black River Mining Co., a joint venture of Armco Inc., and Jones & Laughlin Steel Corp., initiated the construction in 1979 of a $4 million, 30-ton-per-hour, hydrated lime adjunct to its quicklime plant in Butler, Ky. Also added will be a pulverized quicklime facility. Scheduled completion is for late 1980.[8]

Steetley Industries Ltd. of Hamilton, Ontario, the Canadian subsidiary of Steetley Co. Ltd. of England, announced in September 1979 that its U.S. subsidiary, Steetley Resources Inc., had purchased National Gypsum Co.'s dolomitic lime plant at Gibsonburg, Ohio, with an acquisition cost of $2.25 million. Production, principally for the steel industry, is expected in early 1980. Subsequently, very late in 1979, Steetley also purchased the facilities of the Ohio Lime Co., a wholly owned subsidiary of General Refractories Co., located at Woodville, Ohio, also producing dolomitic quicklime for the steel industry and refractory-grade, dead-burned dolomite.[9]

Tenn-Luttrell Lime Co. of Knoxville, Tenn., initiated installation in 1978 of an 800-ton-per-day, coal-fired lime kiln and ancillary facility at Luttrell, Tenn., 23 miles northeast of Knoxville. Equipment consisted of a Kennedy Van Saun rotary kiln with preheater, a 15-ton-per-hour hydrator, and bagging facilities. Tenn-Luttrell is a joint venture of Penn Virginia Corp. and Luttrell Mining Co. The plant was onstream in late 1979.[10]

Crown Zellerbach Corp. installed a $1 million, 11-1/2-foot-diameter by 330-foot-long Traylor rotary kiln with auxiliaries in 1979 at its paper mill in Camas, Wash. The plant will regenerate lime sludge and has a capacity of 245 tons per day of quicklime.[11]

Energy.—The lime industry in 1978-79 made considerable progress in efficient utilization of energy. The changes resulted in a 12% reduction in energy consumption compared with the base year of 1972. British thermal unit (Btu) consumption per ton of lime produced through the last half of 1979

Table 3.—Lime sold or used by producers in the United States, by size of plant[1]

(Thousand short tons)

Size of plant	1978			1979		
	Plants	Quantity	Percent of total	Plants	Quantity	Percent of total
Less than 10,000 tons	12	64	(2)	17	103	(2)
10,000 to 25,000 tons	38	632	3	27	428	2
25,000 to 50,000 tons	22	859	4	25	958	5
50,000 to 100,000 tons	23	1,619	8	23	1,678	8
100,000 to 200,000 tons	22	3,177	16	24	3,484	17
200,000 to 400,000 tons	31	8,734	43	31	8,711	41
More than 400,000 tons	8	5,401	26	8	5,621	27
Total	156	[3]20,484	100	155	20,983	100

[1] Excludes regenerated lime. Includes Puerto Rico.
[2] Less than 1/2 unit.
[3] Data do not add to total shown because of independent rounding.

was 7.1 million, compared with 7.79 million in 1976 and 8.1 million in 1972.

As reported by the National Lime Association, fuel sources for the lime industry through the second half of 1979 were coal and coke, 69.6%; natural gas, 23.2%; oil (No. 2 and No. 6), 2.2%; electricity, 2.9%; and propane and other, 2.1%. Compared with the base year of 1972, significant improvements were made through 1979 with a 57% reduction in the use of scarce natural gas and a 147% increase in the use of coal and coke.[12]

CONSUMPTION AND USES

Lime was consumed in every State. Leading consuming States were Pennsylvania, Ohio, Indiana, Michigan, Texas, New York, and Illinois, each of which consumed more than 1 million tons. These seven States accounted for 60% of the total lime consumed.

Lime consumption in the steel industry established a new record in 1978 with a 7% increase over 1977 to 9 million tons, equal to 44% of all lime consumed in the United States. Consumption in 1979 was slightly down. Continued high housing and building starts during the biennial period 1978-79 caused modest increases in the sales of mason's and finishing lime, but still below the recent record year of 1973. Environmental uses of lime continued to appreciate rapidly, especially lime consumption in flue gas desulfurization processes which increased 350% during the period.

Leading quicklime-consuming States in 1979 were Pennsylvania, Ohio, Indiana, Michigan, and New York, each of which consumed more than 1 million tons. These five States accounted for 51% of the total quicklime consumed.

Leading hydrate-consuming States in 1979 were Texas, Pennsylvania, Illinois, Ohio, and Louisiana, each of which consumed more than 100,000 tons. These five States accounted for 52% of the total hydrate consumed.

Lime sold by producers in 1979 was utilized for chemical and industrial uses, 89%; construction, 6%; refractories, 4%; and agriculture, less than 1%. Captive lime used by producers was 26% of the total, compared with 29% in 1977. Captive lime was used mainly in BOF (basic oxygen furnace) steel, 31%; alkalies, 23%; and sugar, 13%.

Leading individual uses in 1979 were for BOF steel, water purification, alkalies, paper and pulp, electric steel, and sewage treatment, which together accounted for 63% of the total consumption.

Of the main chemical and industrial uses in 1979, lime for BOF's was produced principally in Ohio (27%), Indiana and Illinois (combined, 26%), and Pennsylvania (12%). Lime for water purification was produced mainly in Missouri (33%); Texas (14%), Pennsylvania (11%), and Alabama (9%). Lime for alkalies was produced mainly in New York, Michigan, and Arkansas. Lime used for paper and pulp, excluding regenerated lime, was produced mainly in Alabama (28%), Virginia (16%), Texas (12%), and Wisconsin (11%). Lime for electric steel was produced mainly in Pennsylvania (29%), Ohio and Texas (12% each), and Missouri (11%). Lime used for sewage treatment was produced mainly in Pennsylvania (24%), Alabama (11%), and Kentucky, Missouri, and Wisconsin (8% each).

Mason's lime was produced at 33 plants in 16 States, including Puerto Rico; leading States were Pennsylvania (21%) and Wisconsin (19%) with four plants each. Finishing lime was produced in 8 States at 11

Table 4.—Destination of shipments of lime sold or used by producers in the United States, by State[1]

(Thousand short tons)

State	1978			1979		
	Quicklime	Hydrated lime	Total[2]	Quicklime	Hydrated lime	Total[2]
Alabama	549	56	605	548	65	612
Alaska	W	W	2	W	W	1
Arizona	380	21	402	493	27	520
Arkansas	151	22	173	167	24	191
California	695	92	787	787	112	898
Colorado	245	16	261	212	17	230
Connecticut	43	16	59	47	17	64
Delaware	21	16	38	40	6	46
District of Columbia	W	W	6	W	W	1
Florida	356	61	417	382	60	441
Georgia	190	42	232	196	31	227
Hawaii	1	4	4	2	5	7
Idaho	87	7	94	97	3	100
Illinois	1,006	152	1,159	910	157	1,068
Indiana	2,114	76	2,191	2,023	74	2,097
Iowa	88	21	109	85	23	108
Kansas	81	17	98	97	24	120
Kentucky	391	28	419	399	20	419
Louisiana	218	115	333	209	140	349
Maine	33	1	34	34	1	35
Maryland	510	19	528	449	24	473
Massachusetts	62	17	79	59	15	74
Michigan	1,802	46	1,848	1,566	37	1,603
Minnesota	207	23	230	229	18	247
Mississippi	132	23	155	146	25	171
Missouri	173	56	229	172	51	223
Montana	205	6	211	227	11	237
Nebraska	63	8	71	69	7	76
Nevada	20	13	33	20	--	20
New Hampshire	W	W	1	W	W	1
New Jersey	104	59	163	82	58	140
New Mexico	77	10	87	89	10	99
New York	879	56	935	1,102	51	1,153
North Carolina	129	30	159	164	28	192
North Dakota	77	9	85	104	8	111
Ohio	2,300	159	2,459	2,237	144	2,380
Oklahoma	81	19	100	102	23	126
Oregon	102	16	118	109	20	130
Pennsylvania	2,284	216	2,500	2,413	249	2,662
Rhode Island	7	2	9	7	10	17
South Carolina	118	21	139	121	11	132
South Dakota	5	18	22	11	19	30
Tennessee	149	78	227	164	70	234
Texas	800	674	1,474	866	672	1,537
Utah	114	33	147	140	22	161
Vermont	W	W	1	W	W	1
Virginia	139	69	208	140	66	206
Washington	131	19	150	257	18	275
West Virginia	344	42	386	387	42	429
Wisconsin	129	56	186	126	51	177
Wyoming	31	9	39	34	17	50
Other States[3]	6	40	39	3	36	39
Total United States[2]	17,836	2,606	20,443	18,160	2,619	20,940
Exports:						
Canada	20	10	31	19	10	29
Other countries	7	4	11	9	5	14
Total exports[2]	27	15	41	28	15	43
Grand total	17,863	2,621	20,484	18,349	2,634	20,983

W Withheld to avoid disclosing company proprietary data; included in "Other States."
[1] Excludes regenerated lime. Includes Puerto Rico.
[2] Data may not add to totals shown because of independent rounding.
[3] Includes Puerto Rico, the Virgin Islands, and States indicated by symbol W.

plants; the leading State was Ohio with 2 plants (40%).

The use of lime in agriculture continued its long-term decline to a low of 71,000 tons in 1979. Compared with its high of 250,000 tons per year in 1956, it has become of small significance. Conversely, the less-reactive, pulverized limestone continued its long-term upward trend with 33 million tons used in 1978.

Table 5.—Lime sold or used by producers in the United States, by use[1]

(Thousand short tons and thousand dollars)

Use	1978				1979			
	Sold	Used	Total[2]	Value	Sold	Used	Total[2]	Value
Agriculture	78	--	78	3,324	71	--	71	3,286
Construction:								
Soil stabilization	627	--	627	25,529	695	--	695	32,340
Mason's lime	348	41	389	15,838	350	41	391	18,209
Finishing lime	177	--	177	7,205	195	--	195	9,093
Other construction uses	25	37	62	2,524	34	35	69	3,203
Total[2]	1,178	78	1,256	51,096	1,274	76	1,350	62,845
Chemical and industrial:								
Steel, BOF	5,905	1,761	7,665	275,848	5,611	1,706	7,317	295,493
Water purification	1,623	8	1,631	58,699	1,631	9	1,640	66,225
Alkalies	5	1,287	1,292	46,493	6	1,252	1,258	50,804
Paper and pulp	1,057	109	1,166	41,964	1,149	109	1,258	50,788
Steel, electric	744	20	764	27,496	964	28	992	40,066
Sewage treatment	650	9	659	23,717	799	16	815	32,902
Sugar refining	55	696	751	27,028	47	727	774	31,277
Copper ore concentration	296	327	622	22,385	427	344	771	31,133
Magnesia from seawater or brine	W	W	622	22,385	W	W	682	27,544
Steel, open-hearth	503	47	550	19,794	603	49	652	26,321
Sulfur removal	330	53	384	13,820	604	--	604	24,393
Acid mine water	188	76	264	9,501	215	70	285	11,515
Aluminum and bauxite	153	114	267	9,609	162	111	273	11,081
Calcium carbide	155	67	222	7,990	146	72	218	8,823
Glass	225	5	231	8,314	191	--	191	7,715
Magnesium metal	W	W	18	648	W	W	177	7,145
Food products	44	12	56	2,015	90	30	120	4,829
Precipitated calcium carbonate	61	52	113	4,067	67	52	119	4778
Petrochemicals	142	15	158	5,686	71	--	71	2,867
Oil well drilling	51	--	51	1,835	62	--	62	2,504
Metallurgy, other	33	4	36	1,296	55	3	58	2,359
Petroleum refining	47	--	47	1,691	53	--	53	2,125
Tanning	24	--	24	864	28	--	28	1,140
Ore concentration, other	10	--	10	360	15	--	15	620
Calcium silicate	--	--	--	--	11	--	11	429
Brick, sand-lime	7	--	7	252	9	--	9	358
Gelatine	--	--	--	--	7	--	7	266
Rubber	7	--	7	252	5	--	5	219
Paint	3	--	3	108	3	--	3	103
Wire drawing	4	(3)	4	144	2	1	3	101
Insecticides	5	--	5	180	2	--	2	63
Other uses[4]	626	519	505	18,173	411	742	296	12,024
Total[2]	12,952	5,181	18,134	652,614	13,446	5,323	18,769	757,960
Refractory dolomite	894	122	1,016	45,881	670	123	793	41,676
Grand total[2]	15,103	5,381	20,484	752,915	15,461	5,522	20,983	865,766

W Withheld to avoid disclosing company proprietary data; included in "Other uses."

[1] Excludes regenerated lime. Includes Puerto Rico.

[2] Data may not add to totals shown because of independent rounding.

[3] Less than 1/2 unit.

[4] Includes chrome, coke (1979), explosives, fertilizer (1978), lithium (1978), silica brick, other uses, and uses indicated by symbol W.

PRICES

The following section contains values and percentages for 1978 and 1979. Those for 1979 are in parentheses.

The average value of lime sold or used by producers was $36.76 ($41.26) per ton, an increase of 10% (23%) over the 1977 price of $33.50 and an increase of 111% (137%) over the 1973 price of $17.42. Values ranged from $35.99 ($40.38) for chemical and industrial lime to $40.68 ($46.56) for construction lime, $45.14 ($52.54) for refractory dolomite, and $42.67 ($46.48) for lime used in agriculture.

Values for quicklime sold ranged from $35.65 ($39.98) for chemical lime to $41.23 ($44.58) for construction lime, $25.56 ($26.96) for lime used in agriculture, and $45.68 ($52.81) for dead-burned dolomite, and averaged $36.40 ($39.76), an increase of 11% (22%) over the 1977 value.

Values for hydrated lime sold ranged from $41.26 ($47.63) for construction lime to $41.71 ($48.27) for chemical lime and $46.18 ($49.64) for lime used in agriculture, and averaged $41.63 ($47.84), an increase of 14% (31%) over the 1977 price.

FOREIGN TRADE

The following section contains foreign trade statistics for 1978 and 1979. Those for 1979 are in parentheses.

Exports of lime increased 36% (1%) to 44,800 (45,400) tons, but were 35% (34%) below the 1968 record. Of the total, Canada received 66% (61%), Surinam received 18% (8%), Guyana received 5% (5%), and Mexico received 4% (16%). The remaining 7% (10%) went to 30 (39) countries. The order of shipments of the remaining 10% in 1979 were as follows: Bahamas, Honduras, Saudi Arabia, Papua New Guinea, Philippines, Bermuda, Brazil, Venezuela, New Zealand, the Netherlands, Egypt, Guatemala, Argentina, Netherlands Antilles, Ireland, Angola, Bahrain, Trinidad, Cayman Islands, Indonesia, Iraq, Turk Islands, Japan, French West Indies, Zaire, Italy, Haiti, Panama, Seychelles, Pakistan, Yemen Arab Republic, Colombia, Republic of South Africa, the United Kingdom, France, Senegal, Singapore, India, and the Dominican Republic.

Imports of lime have grown at an average rate of over 14% during the last 10 years. Imports from Canada, 92% (91%), and Mexico, 8% (9%) were 610,000 (640,000) tons, an increase of 44% (51%) compared with that of 1977. Net import reliance, expressed as a percentage of apparent consumption, was 3%.

Table 6.—U.S. exports of lime

Year	Quantity (short tons)	Value (thousands)
1976	55,852	$2,981
1977	32,954	2,185
1978	44,794	3,082
1979	45,421	3,827

Table 7.—U.S. imports for consumption of lime

	Hydrated lime		Other lime		Total	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1976	48,461	$1,814	316,442	$8,816	364,903	$10,630
1977	52,875	1,878	370,012	11,192	422,887	13,070
1978	62,290	2,491	547,830	16,663	610,120	19,154
1979	85,169	3,450	554,332	19,165	[1]639,500	[1]22,614

[1] Data do not add to totals shown because of independent rounding.

WORLD REVIEW

Lime is produced all over the world, mainly in the heavily industrialized nations. Large quantities of lime are produced in many countries of the world in small, primitive pot and vertical kilns. The quicklime is used in the manufacture of mortar and plaster in the construction of homes and buildings. Production statistics are not reported, and estimates can only be made that the quantities are substantial. Source materials are adequate. The United States, with 17% of the total, ranked second in world production in 1979, following the U.S.S.R.

The Fourth International Lime Congress was held in Hershey, Pa., on September 21-22, 1978. Thirty technical papers presented by principally non-U.S. participants were well received by an international audience of over 500. The next Congress will be held in Paris, France, in 1982.

Australia.—Cockburn Cement Ltd. and Alcoa of Australia (W.A.) Ltd. agreed to a 15-year contract for the supply of quicklime to Alcoa's alumina processing plants at Kwinana and Pinjarra. The modern suspension preheater lime kiln with a capacity of 300,000 tons per year will be installed at Cockburn's South Coogee works. Construction was initiated in late 1977 and scheduled for completion in 1980.[19]

Brazil.—A hydrated lime plant was installed as an integral part of the Samarco iron ore project pelletizing facility at Ponta

Ubu in the State of Espirito Santo. Pebble quicklime is delivered by truck from Minas Gerais and hydrated in Kennedy Van Saun continuous nonpressure-type hydrators with a total capacity of 66 tons per hour. The hydrated lime will be added as a binding agent at a rate of 2.5% to 3.0% in the pelletizing operation.[14]

Canada.—During 1978, 18 companies operated 25 lime plants in Canada: 10 in Ontario, 5 in Alberta, 4 in Quebec, 3 in Manitoba, 2 in British Columbia, and 1 in New Brunswick. Producer shipments were 2.2 million tons in 1978, a 7% increase compared with that of 1977, and increased another 3% in 1979 to 2.3 million tons. In 1978, 4 plants produced dolomitic lime, 1 produced both high-calcium and dolomitic lime, and the balance of 20 plants produced high-calcium lime. The iron and steel industry consumed 33% of total lime shipments, with the pulp industry consuming 13%. Hydrated lime production was only 10% of total lime shipments. The Canadian lime industry averaged 5.5 million Btu's per ton of lime produced in 1978, with an announced goal of 14% improvement in fuel utilization by 1980, over the base year of 1973.[15]

Chile.—A hydrated lime plant with a capacity of 15 tons per hour was installed in 1978-79 by Kubota of Tokyo, Japan, at Chile's first iron ore pelletizing complex, the Huasco Valley project. The hydrated lime was the binder for the "self-fluxing" beneficiated magnetite pellet.[16]

China, Mainland.—Imperial Krauss Maffai Industrieanlagen GmbH of Munich, the Federal Republic of Germany, supplied a 600-ton-per-day lime plant in 1978 to the Government of China. It was to be erected near Wuhan, and will produce a highly reactive lime for the Chinese steel industry.[17]

Czechoslovakia.—An integrated lime and cement plant, built by Pragoinvest, came onstream in Zahorie in late 1978. The lime production line has a capacity of 500 tons per day.[18]

Iran.—Sumitomo Shoji Kaisha of Tokyo, Japan, was awarded a $7.4-million contract by the National Iranian Steel Industries for the construction of a 250,000-ton-per-year quicklime plant. Construction was initiated in 1978 with operation scheduled for 1981.[19]

Ireland.—The Irish Sugar Co.'s factory in Carlow, Ireland, installed a new vertical lime kiln in early 1978 with a capacity of 120 tons per day of quicklime. Manufactured by West's Pyro Ltd., the new oil-fired kiln replaces the two old coke-fired kilns, and is sufficient for a sugar beet throughput of 6,600 tons per day.[20]

Libya.—The largest lime plant in Libya began production in early 1978 near Souk el Khamis. Infrastructure development included the Souk el Khamis high-calcium limestone quarry which yields raw material for transportation to the plant. The calcining plant consists of a Humboldt-Wedag rotary kiln with a capacity of 275 tons per day of quicklime.[21]

Qatar.—The State of Qatar awarded a contract for $5.3 million to Newell Dunford Engineering, Ltd., of London, England, for a lime calcining plant to be built at Umm-Bab near the capital of Dohar for the Qatar National Cement Co. Construction started in 1977, with commissioning scheduled for late 1979.[22]

Saudi Arabia.—A lime manufacturing plant and two sand-lime brick plants were initiated in 1978 and commissioned in early 1980 in Riyadh and Jeddah to supply the burgeoning construction industry. The lime plant produces 200 tons per day of burned lime as feed to two brick plants, which together produce 23,000 bricks per hour. The calcining plant has two shaft kilns, a quicklime pulverizer, and a hydrator.[23]

South Africa, Republic of.—Lime sales rose during 1978 by 20% in volume (to nearly 2.0 million tons in 1978) and 36% in value. Another increase in volume of 41% occurred in 1979 to 2.8 million tons. The consumption pattern is supported by 32% use in the iron and steel industry, and 39% in the other industrial consumers, principally the mining, beneficiation, and metallurgical sectors.[24]

Thailand.—Laterite Products Thailand Co. Ltd. started operation of its first oil-fired lime kiln at Pak Chong District, Nakkon Ratchasima Province, in July 1979. The kiln capacity was 110 tons per day of quicklime which will be used as a basic raw material for production of laterite-lime, a high-strength, fire-resistant building material. A second kiln was scheduled for installation early in 1980. Total plant cost was $530,000.[25]

United Kingdom.—The Shapfell quarry and lime plant located in Cumbria, Scotland, is the British Steel Corp.'s only major producer of high-quality metallurgical lime for its Ravenscraig's steel plant basic oxygen steelmaking process. Three kilns, fueled by liquid petroleum gas, have a capacity of 6,900 tons per week of quicklime.[26]

Yugoslavia.—Two new lime plants were completed near Kucevo, Serbia, in 1978. Construction was started on a new 70,000-ton-per-year lime plant at Jelen Do, near Cacak, Serbia, and construction planning was begun for a 120,000-ton-per-year plant near Slavonski Brod, Croatia.[27]

Table 8.—Quicklime and hydrated lime, including dead-burned dolomite: World production, by country

(Thousand short tons)

Country[1]	1976	1977	1978[p]	1979[e]
North America:				
Canada	2,039	2,094	2,242	[2]2,306
Costa Rica[e]	6	7	8	10
Dominican Republic	19	24	23	22
Guatemala	50	51	49	50
Jamaica	[e]269	205	168	170
Nicaragua[e]	[r]29	[r]40	41	40
United States, including Puerto Rico, (sold or used by producers)	20,257	19,987	20,484	[2]20,926
South America:				
Brazil[e]	4,740	4,960	4,960	4,960
Chile[e]	660	680	680	700
Colombia[e]	1,100	1,430	1,430	1,430
Paraguay	35	39	42	50
Peru	([3])	([3])	([3])	([3])
Uruguay	77	77	94	90
Europe:				
Austria	[r]1,057	1,068	1,120	1,010
Belgium	2,540	2,553	2,540	2,600
Bulgaria	1,763	1,901	[e]2,000	2,000
Czechoslovakia	3,292	3,330	3,393	3,300
Denmark	255	191	179	180
Finland	285	259	214	220
France	[r]5,124	4,925	[e]5,070	5,100
German Democratic Republic	3,752	[e]3,711	3,795	3,900
Germany, Federal Republic of	[r]10,192	9,667	9,910	9,900
Hungary	[r]807	819	816	820
Ireland	76	88	101	100
Italy	[r]2,412	2,421	2,360	2,300
Malta	[r]30	35	31	33
Norway	99	[e]110	[e]110	110
Poland[4]	[r]8,947	9,521	10,070	10,600
Portugal	245	250	[e]280	300
Romania	3,660	3,798	4,031	4,000
Spain[e]	440	440	390	440
Sweden (sales)	945	848	[e]1,040	900
Switzerland	78	73	75	77
U.S.S.R.[e]	25,000	26,000	26,000	26,000
Yugoslavia	2,124	2,256	[e]2,490	2,800
Africa:				
Algeria[e]	[r]36	44	55	90
Burundi	[r]([3])	[e]([3])	([3])	([3])
Egypt[e]	90	100	100	100
Kenya	33	86	55	80
Libya	358	1,102	243	250
Malawi[e]	([3])	([3])	([3])	([3])
Mauritius	8	9	9	9
Mozambique	[r] [e]110	[e]110	[e]10	10
South Africa, Republic of (sales)	1,529	1,658	2,067	[2]2,800
Tanzania[e]	2	2	3	3
Tunisia	351	373	471	470
Uganda[e]	[r]22	[r]22	28	30
Zaire	[r] [e]120	111	110	110
Zambia	159	280	280	280
Asia:				
Cyprus	[r]35	31	17	20
India[e]	[r]200	200	220	450
Iran[e]	1,100	1,100	1,000	550
Israel	220	112	137	130
Japan	10,115	9,945	9,985	10,000
Jordan	3	3	3	3
Korea, Republic of	[e]120	66	[e]66	66
Kuwait	13	22	4	13
Lebanon	[e]200	179	111	110
Mongolia	[r] [e]40	41	40	40
Philippines	30	31	36	40
Saudi Arabia[e]	17	22	33	40
Taiwan	181	175	212	[2]177
Oceania:				
Australia	994	944	[e]955	1,100
Fiji Islands	3	2	([3])	([3])
New Zealand[e]	[r]180	190	175	190
Total	[r]118,673	120,818	122,657	124,556

[e] Estimate. [p] Preliminary. [r] Revised.

[1] Lime is produced in many other countries besides those listed. Mainland China, Mexico, Venezuela, and the United Kingdom are among the more important countries for which official data are unavailable.

[2] Reported figure.

[3] Less than 1/2 unit.

[4] Excludes output by small producers.

TECHNOLOGY

The Fuller Co. has developed a system of processing limestone fines using a flash calciner with a preheater consisting of from one to three cyclones. Flexibility for coarser fines is provided by the use of either a fluidized bed or a short rotary kiln. The calcined material is removed using a disengaging cyclone and sent to cyclone cooling stages. A 500-ton-per-day system will use 4.5 million Btu's per ton of lime produced, and can use either gas, oil, or coal.[28]

Heat loss through walls of rotary lime kilns can be reduced by adding and maintaining an adequate refractory lining, and can be further reduced by adding a chain system or lifters which agitates the material being heated, insuring greater heat penetration.[29]

Production of lime has risen from 150 to 200 tons per day at the new installation of a four-plunger, two-bay preheater on the lime kiln at the Grantsville, Utah, plant of the U.S. Lime Div. of The Flintkote Co. Greater fuel efficiency and lowered maintenance has also resulted.[30]

Lateritic soil is an end product of severe weathering and leaching of different rocks found in much of the warm temperate regions of the earth. Pressed mixtures of slaked lime and laterite, moist-cured below 100° C, can produce high-strength building blocks which have good technical properties.[31] (See also Thailand in World Review.)

Lime is produced in South Africa primarily in coal-fired rotary kilns. Ashrings develop rapidly and are massive, weighing as much as 70 tons in larger kilns. Blasting after wet drilling has resulted in downtime savings of up to 2 days.[32]

A new concept in agricultural liming is attracting attention. Rather than dry bulk spreading, fluid fertilizer equipment is used, utilizing liquid suspensions of lime. Usually minus 100-mesh material, suspended with attapulgite clay and containing a dispersing agent, has met with the greatest success.[33]

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Lithium

By Richard H. Singleton and James P. Searls[1]

The United States continued to be both the world's largest producer and the world's largest consumer of lithium minerals and chemicals. The United States was self-sufficient in this commodity and was the world's largest exporter. Production declined an estimated 5% in 1978 and stayed at that level in 1979. Imports were insignificant in 1978 and were minor in 1979. Exports were estimated to have increased in 1978 by 11% and in 1979 by 20%. Estimated apparent consumption declined 17% in 1978 and 15% in 1979.

World supply of lithium as mineral concentrates and brines declined about 7% to 8,300 short tons of contained lithium in 1978 and rose to 8,500 tons in 1979. World consumption (after processing losses) was estimated to be down 7% in 1978 to 7,100 short tons of contained lithium and up 6% in 1979 to 7,500 short tons of contained lithium. Aluminum production continued to be the world's largest end use for lithium. About one-third of U.S. and one-fifth of Western European aluminum potlines used lithium. Lithium was apparently not used in Japanese aluminum potlines in 1978 but its use in 1979 was uncertain.

The People's Republic of China tentatively entered the market with exports of 1 metric ton of lithium hydroxide and nearly 11 metric tons of lithium carbonate to Japan in 1979.

The United States and the U.S.S.R. are the primary lithium producers. The United States continued to supply about three-fourths of demand in nonproducing countries; the remainder was supplied by the U.S.S.R. as chemicals, and by Zimbabwe (Rhodesia) as mineral concentrate. China is producing small amounts for export while Brazil, Portugal, and Argentina produce mostly for internal consumption. The Federal Republic of Germany and Japan are large importers of lithium carbonate, which they convert for use or resale to their export markets. France, Belgium, and the Netherlands also import for conversion and resale. Australia has not produced lithium ores since 1974. Termination of lithium production in 1978 by Kerr-McGee Chemical Corp. in California resulted in two approximately equal sized producers in the United States.

Legislation and Government Programs.—In 1978 the General Services Administration (GSA) sold about 30 short tons (5 short tons of contained lithium) of lithium hydroxide monohydrate. This material is excess from a nuclear weapons program, not from the Strategic Stockpile. GSA reports that it has 11,500 short tons (1,898 short tons of contained lithium) of virgin lithium hydroxide monohydrate and 28,500 short tons (4,703 short tons of contained lithium) of depleted lithium hydroxide monohydrate (depleted of lithium 6) that may contain 8 to 9 parts per million of mercury. None of these materials were sold in 1979.

The U.S. Congress voted in late fall of 1979 to lift the trade sanctions with Zimbabwe (Rhodesia). This again will allow direct exporting of Zimbabwean lithium ores to the United States.

Table 1.—Salient statistics on lithium

(Short tons of contained lithium)

	1975	1976	1977	1978	1979
United States:					
Production[1]	W	W	W	W	W
Yearend producers' stocks[1]	W	W	W	W	W
Imports[1]	90	10	10	10	50
Shipments of government stockpile surplus[2]	61	164	253	5	--
Supply[1] [3]	4,440	5,200	6,900	6,300	6,300
Supply[e] [3] [4]	3,790	4,400	5,900	5,400	5,600
Exports[e] [2]	900	1,600	1,800	2,000	2,400
Apparent consumption[e] [2]	2,890	2,800	4,100	3,400	3,200
Rest of world:					
Production[e] [1]	2,000	2,000	2,000	2,000	2,250

[e] Estimate. W Withheld to avoid disclosing company proprietary data.

[1] Mineral concentrate.

[2] Chemicals.

[3] Production plus inventory decrease.

[4] A 15% loss was assumed in converting supply from mineral concentrate to the chemical form. Changes in producers' inventories of lithium chemicals were unknown and were assumed to be zero. An estimated 50 short tons of imported chemicals are included.

DOMESTIC PRODUCTION

There were two lithium producers in the United States in 1979. Foote Mineral Co., 92% owned by Newmont Mining Corp., produced lithium from pegmatite dikes in North Carolina and from subsurface brines in Nevada. Lithium Corporation of America, owned by Gulf Resources and Chemical Corp., produced lithium from pegmatite dikes in North Carolina. Kerr-McGee terminated Li_2CO_3 production at its Searles Lake brine facility in California in 1978. Production and sales reported to the Bureau of Mines are withheld to avoid disclosing company proprietary data.

According to a published report,[3] Foote Mineral Co. produced approximately 5,000 short tons of Li_2CO_3 (940 short tons of contained lithium) in 1978 and 6,000 short tons of Li_2CO_3 (1,128 short tons of contained lithium) in 1979 from its Kings Mountain, N.C., plant. Foote's Silver Peak, Nev., plant produced approximately 7,000 short tons Li_2CO_3 (1,316 short tons of contained lithium) in both 1978 and 1979.

Lithium Corporation of America (Lithcoa) reported production of 95% of capacity in 1978 and 107% capacity in 1979 in a published report.[4] Since their capacity was 14,000 short tons of lithium carbonate per year this was 13,300 short tons (2,500 short tons of contained lithium) in 1978 and 15,000 short tons (2,800 short tons of contained lithium) in 1979. Lithcoa reports that 43% of sales were to foreign customers. Lithcoa has announced plans to expand capacity by 4,000 short tons of lithium carbonate by 1982.

CONSUMPTION AND USES

Some mineral concentrate, possibly as much as 10%, was used directly by the ceramics industry, but most concentrate is converted to lithium chemicals and metal. The Bureau of Mines estimates a 15% loss in conversion from ore to lithium carbonate. Lithium chemicals are used by the aluminum, air conditioning, ceramic, specialty glasses, synthetic rubber, thermoplastic, grease, and battery industries.

Apparent domestic consumption of all lithium-containing products is estimated to have decreased by 17% in 1978 and 6% in 1979. Changes in producers' inventories are unknown and assumed to be zero. In 1978 consumption turned downwards in all major end-use categories except butyllithium and lithium hydroxide for grease manufacture. In 1979 consumption declined generally except for increases in foil sales for small batteries, level lithium consumption by aluminum smelters, and continued strong demand for butyllithium and lithium hydroxide.

PRICES

Domestic prices for lithium chemicals increased approximately in accordance with the cost-of-living index. The price for lithium metal increased more, probably due to energy costs.

Table 2.—Domestic mid-year producer's prices of lithium and lithium compounds

(Dollars per pound)

	1978	1979
Lithium bromide, 54% brine: 2,268-pound lots, delivered in drums	2.68	2.93
Lithium carbonate, technical: Truckload lots, delivered	.955	1.025
Lithium chloride, anhydrous, technical: Truckload lots, delivered	1.54	1.70
Lithium fluoride	3.29	3.42
Lithium hydroxide monohydrate: Truckload lots, delivered	1.30	1.40
Lithium metal ingot: 1,000-pound lots, f.o.b	13.20	15.65
Lithium sulfate, anhydrous	1.73	1.93
N-butyllithium in n-hexane (15%): 3,000-pound lots, delivered	8.38	9.06

FOREIGN TRADE

U.S. exports of lithium chemicals (shown in tables 3 and 4) are not completely reported in available U.S. trade statistics. However, review of trade data of major lithium-importing countries indicates that U.S. exports, mainly lithium carbonate, increased approximately 10% in 1978 and 20% in 1979. U.S. imports are shown in table 5.

Table 3.—U.S. exports of lithium compounds in 1978 and 1979

(Gross weight)

Country	1978		1979	
	Quantity (pounds)	Value (dollars)	Quantity (pounds)	Value (dollars)
Algeria	--	--	9,262	10,484
Argentina	46,331	37,786	51,181	63,123
Australia	151,341	366,001	251,476	466,190
Austria	--	--	4,784	5,445
Belgium	26,926	47,722	127,317	184,512
Bermuda	--	--	1,240	3,145
Brazil	28,022	85,142	35,785	44,645
Cameroon	4,654	3,952	--	--
Canada	2,796,993	1,790,804	1,591,898	1,839,050
Chile	5,930	11,420	--	--
Colombia	8,843	16,086	10,600	17,653
Costa Rica	110	1,000	15,706	11,634
Denmark	--	--	100	2,640
Dominican Republic	6,752	6,840	5,700	5,580
Ecuador	13,485	20,668	--	--
Egypt	4	800	--	--
France	144,379	195,050	49,415	83,554
French Pacific Island	2,500	3,225	2,635	3,225
German Democratic Republic	--	--	10,931	69,014
Germany, Federal Republic of	6,665,318	5,710,666	7,264,390	6,703,216
Greece	--	--	16,800	2,684
Guinea	228	1,050	--	--
Hong Kong	108	1,200	2,000	3,700
Iceland	44,802	38,843	--	--
India	24,931	32,994	17,137	23,980
Indonesia	1,565	4,092	3,086	3,432
Iran	166,580	204,913	32,595	44,775
Iraq	7,130	8,820	--	--
Ireland	2,289	4,868	2,402	8,756
Israel	39,479	82,219	2,105	38,800
Italy	19,569	25,570	10,412	19,596
Ivory Coast	368	1,021	--	--
Japan	3,055,061	2,587,624	4,048,992	3,735,021
Korea, Republic of	99,542	112,810	261,867	229,844
Lebanon	8,000	7,920	7,200	11,340
Libya	479	1,185	--	--

Table 3.—U.S. exports of lithium compounds in 1978 and 1979 —Continued

(Gross weight)

Country	1978		1979	
	Quantity (pounds)	Value (dollars)	Quantity (pounds)	Value (dollars)
Malaysia	10,817	12,021	2,067	3,370
Mexico	716,136	373,292	413,765	586,497
Netherlands	465,228	436,129	367,924	401,000
New Zealand	440	1,443	2,646	5,345
Pakistan	23,861	29,128	21,491	50,277
Peru	--	--	4,518	11,200
Portugal	3,200	8,926	--	--
Saudi Arabia	55,277	134,830	22,0303	23,418
Sierra Leone	59	816	--	--
Singapore	--	--	644	3,069
South Africa, Republic of	132,588	97,410	59,083	50,975
Spain	1,260	1,772	2,320	6,972
Surinam	60	1,180	--	--
Sweden	659	62,836	--	--
Switzerland	579,181	548,975	510	8,216
Syria	3,078	6,388	2,448	2,448
Taiwan	112,855	107,940	9,796	17,778
Thailand	21,062	770	--	--
United Arab Emirates	--	--	2,095	3,908
United Kingdom	631,677	734,228	683,843	1,154,946
Venezuela	1,297,086	1,303,904	3,158,386	3,135,315
Yugoslavia	3,136	3,453	--	--
Total	17,429,384	15,277,752	18,788,855	19,109,744

Source: U.S. Department of Commerce, Bureau of the Census.

Table 4.—U.S. exports of lithium hydroxide

Destination	1978		1979	
	Quantity (pounds)	Value (dollars)	Quantity (pounds)	Value (dollars)
Argentina	48,400	61,406	123,000	172,790
Australia	157,950	209,312	140,400	192,496
Belgium	--	--	60,800	70,528
Bolivia	--	--	22,526	33,301
Brazil	871,164	1,102,822	726,667	896,088
Canada	259,766	275,258	352,342	478,565
Chile	29,665	40,684	53,514	76,544
Colombia	6,900	10,826	40,709	56,094
Ecuador	--	--	7,920	11,369
Egypt	1,160	1,712	--	--
France	154,000	190,033	123,258	170,524
Germany, Federal Republic of	282,311	366,110	890,164	1,158,727
Greece	--	--	4,404	5,615
India	17,700	24,710	30,020	42,848
Ireland	3,294	8,310	--	--
Israel	--	--	26,400	33,474
Italy	20,000	27,356	11,000	14,925
Japan	630,044	781,879	1,004,263	1,402,752
Malaysia	64,684	51,141	--	--
Mexico	316,794	399,394	296,800	394,086
Morocco	--	--	11,200	15,389
Netherlands	24,640	28,004	44,880	56,395
New Zealand	13,014	19,464	13,200	17,976
Peru	8,000	10,400	8,000	10,400
Philippines	46,000	62,729	43,825	60,454
Portugal	--	--	6,660	9,398
Singapore	--	--	44,511	56,265
South Africa, Republic of	252,244	333,968	306,789	401,764
Spain	44,000	57,420	33,002	45,342
Sweden	33,600	43,456	163,572	212,951
Taiwan	--	--	1,102	2,075
Thailand	22,330	29,910	39,992	60,951
United Kingdom	683,739	862,604	1,101,587	1,484,108
Venezuela	89,600	118,426	65,600	88,528
Total	4,080,999	5,116,849	5,797,997	7,727,722

Source: U.S. Department of Commerce, Bureau of the Census.

Table 5.—U.S. imports for consumption of lithium bearing materials

Commodity and country	1978			1979		
	Gross weight (pounds)	Value (thousand dollars)		Gross weight (pounds)	Value (thousand dollars)	
		Customs	C.I.F.		Customs	C.I.F.
Lithium ores:						
Canada	NA	NA	NA	1,010,540	19	23
Norway	NA	NA	NA	2,442,180	44	63
South Africa, Republic of	NA	NA	NA	5,328,518	353	369
Total	NA	NA	NA	8,781,238	416	455
Lithium compounds:						
Canada	7,700	6	8	1,000	1	1
France	23,216	263	267	43,399	1,821	1,837
Germany, Federal Republic of	856	39	41	10,234	162	167
Israel	--	--	--	44	1	1
Japan	--	--	--	5	2	3
Switzerland	7	(1)	(1)	--	--	--
United Kingdom	84	6	6	35	8	8
Total	31,863	314	322	54,717	1,995	2,017
Lithium salts:						
Denmark	46	1	1	58	2	2
Germany, Federal Republic of	48	15	15	55	20	20
Switzerland	--	--	--	198	1	1
United Kingdom	--	--	--	17	(1)	(1)
Total	94	16	16	328	23	23

NA Not available.

[1] Less than 1/2 unit.

Source: U.S. Department of Commerce, Bureau of the Census.

WORLD REVIEW

Canada.—The Tantalum Mining Corp. of Canada, Ltd.'s deposit at Bernic Lake, Manitoba, interesting for its tantalum, rubidium, and cesium content, is under active consideration for its lithium content. A former partner, International Chemalloy Corporation, went into receivership and Hudson Bay Mining and Smelting has become the new partners after much litigation. The alternatives studed are whether to mine to sell concentrate to the ceramics industry or to produce lithium carbonate for a wider variety of users. One estimate of the planned capacity for this plant is 10,000 tons per year Li_2CO_3 or 1,880 tons of contained lithium.

The Sullivan Mining Group, Ltd., owner of a mine and plant near Val d' Or, Quebec, that had produced spodumene concentrate and lithium chemicals between 1955 and 1965, considered resuming production. The complex was reported to be fairly intact. A pilot study of production of lithium carbonate by a continuous process using soda ash had been completed in 1977. The previous process had been a batch operation.

Chile.—Foote Mineral Co. is negotiating to form the Soc. Chilence del Litio, a joint venture with the Chilean Government to produce lithium from the brines of the Salar de Atacama in northern Chile, east of Antofagasta. Foote Mineral Co. seeks a 55% interest in the new joint venture company. The zone of interest in the salar is 1,400 square kilometers, testing 1.7 grams per liter lithium concentration. The resource is estimated at 4 million tons of contained lithium with reserves at 1.5 million tons. The initial feasibility studies have considered that a 5,500-ton-per-year lithium carbonate plant will be started in 1983. Estimates of the capital cost range from $25 million to $33 million.

France.—Prospecting activities have revealed a deposit of unknown size in central France that contains lithium. This would be important to Europe as an indigenous source of lithium.

United Kingdom.—Lithium Corporation of America began constructing a plant near Liverpool to produce and market lithium products for the European market. It will be

Table 6.—Lithium minerals: World production, by country

(Short tons)

Country[1] and minerals produced	1976	1977	1978[p]	1979[e]
Argentina (minerals not specified)	744	454	1,047	1,000
Brazil:				
Amblygonite	204	539	489	500
Lepidolite	1,468	638	579	600
Petalite	1,067	1,133	1,028	1,100
Spodumene	455	123	112	110
Canada, spodumene[2]	[r]68	--	--	--
China: Mainland (minerals not specified)[e] [3]	10,000	11,000	11,000	11,000
Mozambique:				
Lepidolite[e]	800	(5)	--	--
Spodumene[e]	30	(5)	--	--
Portugal, lepidolite	1,213	1,323	882	900
Rhodesia, Southern (minerals not specified)[e] [3]	10,000	10,000	8,800	8,800
Rwanda, amblygonite[e]	30	30	30	30
South-West Africa, Territory of (minerals not specified)[4]	[r]6,520	2,809	NA	3,000
U.S.S.R. (minerals not specified)[e] [3]	50,000	55,000	55,000	55,000
United States (minerals not specified)	W	W	W	W

[e] Estimate. [p] Preliminary. [r] Revised. NA Not available. W Withheld to avoid disclosing company proprietary data.

[1] In addition to the countries listed, other nations may produce small quantities of lithium minerals, but output is not reported and no valid basis is available for estimating production levels.

[2] Data represent U.S. imports from Canada; official Canadian sources report no production since 1965, but the United States has imported lithium minerals in most years since that time. It is not clear whether these imports are from: (1) accumulated stocks; (2) test production quantities not reported in official Canadian statistics; (3) Canadian imports; (4) any combination of these sources.

[3] These estimates denote only an approximate order of magnitude; no basis for more exacting estimates is available. Output by Mainland China and the U.S.S.R. have never been reported. Southern Rhodesian output has not been reported since 1964.

[4] Output has not been officially reported since 1966, but presumably has continued since a number of countries record imports from "South Africa," which no longer produces lithium minerals. Data given represent imports by the United States. EEC and Spain reported as originating in South Africa, but the reader is cautioned that a portion of this material may have been mined in Southern Rhodesia. In 1966 actual output from South-West Africa totaled 1,739 short tons including amblygonite-30; lepidolite-365; petalite-1,344.

[5] Revised to zero.

a subsidiary called Lithium Corporation of Europe Ltd. and will concentrate on converting imported lithium metal into catalyst compounds and lithium chloride.

European Economic Commission.—The European Commission has imposed a special duty on lithium hydroxide imported into the EEC from the United States and the U.S.S.R. This follows an investigation of alleged dumping. The levy is the equivalent of the difference between the standard price and the actual price. Foote Mineral Co. was exempted, since it had previously agreed to respect the standard price.

Zimbabwe-Rhodesia.—With the lifting of trade sanctions, lithium ores from this country will again be reaching the international market.

TECHNOLOGY

Bench-scale experiments conducted by the Bureau of Mines during 1978 revealed that 82% of the lithium contained in a high-grade hectorite clay could be extracted by a potassium chloride plus calcium sulfate or a potassium chloride plus calcium carbonate roast at 1,000Å C followed by a water leach. The fine-grained hectorite-type clay was representative of an approximately 0.4-percent-lithium-content deposit near McDermitt, Nev., estimated to contain a significant tonnage of lithium.

Development of a lithium-metal sulfide battery continued under U.S. Department of Energy sponsorship and Argonne National Laboratory guidance. This battery has a solid lithium-aluminum alloy anode, an iron sulfide cathode (either FeS or FeS_2), a molten LiCl-KCl near-eutectic electrolyte, and a separator made of boron nitride. The first design was to operate at 400° C and would have a storage capacity of about 100 watt-hours per kilogram, about four times that of a lead-acid storage cell.[8] Cell lives of 1,000 cycles had been obtained in the laboratory. A prototype lithium-battery powerpack was to be built and tested. The 1,500-pound powerpack was to consist of 120 series-connected lithium-FeS cells enclosed in a stainless steel case that measured 11x38x60 inches. It was designed to store about 2.5 times as much energy as a conventional lead-acid battery pack of the same weight and to have a 200-cycle life and a

100-mile range at about 45 miles per hour. Major problems remaining were (1) the high cost of the boron nitride separator, (2) development of a suitable low-cost lightweight insulating container for the vehicular powerpack, and (3) the high cost of the cathode conducting grid for the higher energy second-generation FeS_2 cathode (the more reactive FeS_2 material had attacked all viable grid materials except molybdenum). Development during the next 5 years was aimed at increasing the energy-storage-to-weight ratio by 50%. This would probably require use of the more reactive FeS_2 cathode. Commercial realization of a lithium-metal sulfide battery was not expected before the late 1980's.

Another storage battery developed by Exxon Research and Engineering was reported.[6] Cathode operation was based on the entrance of small lithium cations between the layers of the crystal lattices of certain materials such as refractory metal disulfides. The process, called "intercalation," is reversible. A cell consists of a lithium-metal sheet anode; a metal sulfide cathode such as a sulfide of titanium, TiS_2, or vanadium, VS_2; and an organic electrolyte such as lithium perchlorate, $LiClO_4$, in propylene carbonate. Small cells were reported to have been made available commercially for watches and calculators. A modest research program began at Bell Telephone Laboratories to develop a similar battery as an improved standby source for telephones or semiconductor memory systems.

The second generation of fuel cells, the molten carbonate cell, is a future lithium user. Lithium ceramics are used to separate the anode and the cathode while lithium carbonate and potassium carbonate are the electrolyte. The developers of these cells do not expect them to make a significant demand for lithium before the late 1980's.

The Massachusetts Institute of Technology reported in 1978 that it had developed a specialized powder metallurgy approach to fabricating an aluminum-lithium alloy for potential aircraft structural use in a study sponsored by the National Science Foundation.[7] Small, homogeneous alloy flakes were first made by rapid cooling of liquid alloy between closely spaced metal rolls. The flakes were then sealed into an aluminum container which was extruded at 400° C to produce a sound billet. In addition to decreasing the density, the lithium addition reportedly increased both the strength and fatigue resistance of certain aluminum alloys. Aluminum-based alloys with lithium had never become commercially feasible, mainly because of poor formability.

In 1978 during a nuclear fusion development program, Argonne National Laboratory operated a 50-gallon lithium-metal test loop successfully for more than 2,000 hours.[8] This test loop provided the first circulating lithium system experience on a significant scale for the fusion program. The next demonstration step, already underway at Argonne in 1978, was to use a molten salt to extract tritium from lithium metal. This was to be followed by electrolysis of the salt to evolve and recover the tritium. The major objective of the project was to provide a definitive demonstration of tritium recovery and purity control technology near the 1 part per million tritium concentration level under projected fusion reactor operating conditions.

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[1] Physical scientist, Section of Nonmetallic Minerals.

[2] All tonnages reported in the text are in lithium equivalents unless otherwise specified. One lithium equivalent = 5.32 lithium carbonate equivalents.

[3] See company 10-K reports for 1978 and 1979 filed with the Securities and Exchange Commission, Washington, D.C.

[4] Work cited in footnote 3.

[5] Argonne National Laboratory. Engineering Development of Lithium/Metal Sulfide Battery Technology for Vehicular Propulsion. Summary Report for October 1977 to September 1978. U.S. Department of Energy Contract W-31-109-Eng-38. ANL-79-1, 29 pp. Available from Argonne National Laboratory, Argonne, Ill.

[6] Chemical & Engineering News. New Materials Boost Battery Research. V. 56, No. 40, Oct. 2, 1978, pp. 14-15.

[7] Chemical Week. Splat Cooling Produces Aluminum-Lithium Alloy. V. 122, No. 5, June 21, 1978, p. 30.

[8] Energy Insider. New Argonne Facility Testing Tritium Recovery Technique. V. 1, No. 17, May 29, 1978. Published biweekly by the U.S. Department of Energy, Office of Public Affairs, Forrestal Bldg., Mailstop 8G031, Washington, D.C 20585.

[illegible] sponsored by the National Science Foundation [illegible]

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Magnesium

By Benjamin Petkof[1]

Primary domestic magnesium metal production continued its upward trend in 1978-79. Consumption in 1978 was almost identical to that of 1979 but was above the consumption levels of recent years. Exports of metal increased in both quantity and value. Imports increased in 1978 in both quantity and value but declined in 1979. The quoted metal price advanced in 1978-79. World primary metal production was also up.

Legislation and Government Programs.—New tariff rates for imported magnesium metal resulted from the 1979 Tokyo round of tariff negotiations giving most nations "most-favored nation" status. The tariffs for these nations will decline annually, in stages, beginning January 1, 1980, and ending January 1, 1987.

Table 1.—Salient magnesium statistics

(Short tons)

	1975	1976	1977	1978	1979
United States:					
Production:					
Primary magnesium[1]	120,208	119,957	125,958	149,507	162,291
Secondary magnesium	27,873	30,553	32,694	36,228	37,222
Shipments: Primary	W	W	W	W	W
Exports	32,591	13,444	28,061	41,807	54,275
Imports for consumption	7,903	14,907	5,964	6,668	4,754
Consumption	94,167	104,453	103,576	108,958	108,844
Price per pound cents	82	87-92	96-99	99-101	101-109
World: Primary production	258,487	[r]270,483	[r]277,873	312,268	334,582

[r] Revised. W Withheld to avoid disclosing company proprietary data.

[1] Derived from data reported by The Magnesium Association and the Canadian Department of Mines and Natural Resources. Figures are the difference between total North American production reported by the International Magnesium Association and Canadian production reported by the Canadian Department of Mines and Natural Resources.

DOMESTIC PRODUCTION

Domestic primary ingot production increased substantially in 1978-79 over that of 1977. Four companies accounted for the entire domestic output. Three of these companies, The American Magnesium Company (Snyder, Tex.), The Dow Chemical Co. (Freeport, Tex.,) and NL Industries, Inc. (Rowley, Utah), produced magnesium from magnesium chloride solution obtained from brine by the electrolytic method. Northwest Alloys, Inc. (Addy, Wash.), produced magnesium from dolomite using the silicothermic process. The total nominal U.S. production capacity reached 181,500 tons at the end of 1979.

At midyear 1979, The Dow Chemical Company announced the construction of a plant at Freeport, Tex., to prepare magnesium metal granules for use in steel desulfurization. The plant was expected to be in operation in mid-1980.

Magnesium obtained by secondary recovery continued to supply a signifignant portion of the domestic supply of this metal. Production of secondary metal increased in 1978 and in 1979.

Table 2.—Magnesium recovered from scrap processed in the United States, by kind of scrap and form of recovery

(Short tons)

	1975	1976	1977	1978	1979
Kind of scrap:					
New scrap:					
Magnesium-base	4,076	2,838	3,363	4,634	5,025
Aluminum-base	14,014	16,186	16,807	17,501	18,315
Total	18,090	19,024	20,170	22,135	18,316
Old scrap:					
Magnesium-base	4,873	5,500	5,255	5,522	4,778
Aluminum-base	4,910	6,029	7,269	8,571	9,104
Total	9,783	11,529	12,524	14,093	13,882
Grand total	27,873	30,553	32,694	36,228	37,222
Form of recovery:					
Magnesium alloy ingot[1]	2,796	3,569	3,785	4,272	3,739
Magnesium alloy castings (gross weight)	750	836	859	956	790
Magnesium alloy shapes	1,262	335	932	1,909	2,176
Aluminum alloys	20,328	23,595	25,211	27,301	23,833
Zinc and other alloys	12	15	21	19	13
Chemical and other dissipative uses	44	28	43	48	47
Cathodic protection	2,681	2,175	1,843	1,723	1,600
Total	27,873	30,553	32,694	36,228	37,222

[1] Includes secondary magnesium content of both secondary and primary alloy ingot.

CONSUMPTION AND USES

Total consumption of magnesium metal was almost the same in both 1978 and 1979 but was above that of 1977. Annual consumption during 1978-79 did not reach the peak 1974 consumption level. Magnesium metal was used to manufacture structural products that included cast and wrought items and for sacrificial uses where advantage was taken of the metal's chemical and alloying properties. The metal's useful structural properties, such as low specific weight, good machinability, hot formability, and high strength-to-weight ratio resulted in almost one-fifth of the 1978 and 1979 consumption being used in aircraft, automotive, and other types of transportation equipment, material-handling equipment, and the manufacture of items such as power tools. Slighty over one-half of the magnesium was used for alloying with other metals. The remainder was used for other sacrificial purposes such as cathodic protection, nodular iron production, chemicals, and reducing agents for metals such as titanium, zirconium, uranium, and beryllium.

Table 3.—Consumption of primary magnesium in the United States, by use

(Short tons)

	1975	1976	1977	1978	1979
For structural products:					
Castings:					
Die	6,392	4,759	5,011	5,575	5,182
Permanent mold	1,144	1,059	1,048	1,012	1,069
Sand	1,952	1,233	1,142	1,064	1,209
Wrought products:					
Extrusions	6,215	6,449	(1)	6,301	6,420
Sheet and plate	(1)	(1)	(1)	4,375	4,925
Other (includes forgings)	3,451	3,792	12,632	399	217
Total	19,154	17,292	19,833	18,726	19,022
For distributive or sacrificial purposes:					
Alloys:					
Aluminum	46,670	54,320	56,086	58,798	60,549
Copper	13	14	10	12	9
Zinc	15	29	23	21	15
Other	11	10	8	8	8
Cathodic protection (anodes)	4,702	7,809	4,083	6,600	6,769
Chemicals	8,681	10,140	9,941	(1)	(1)
Nodular iron	6,775	7,584	7,297	7,956	4,335
Scavenger and deoxidizer	(1)	(1)	(1)	(1)	(1)
Reducing agent for titanium, zirconium, hafnium, uranium, and beryllium	7,007	5,985	5,235	6,230	7,435
Other, including powder	1,139	1,270	1,060	10,607	10,702
Total	75,013	87,161	83,743	90,232	89,822
Grand total	94,167	104,453	103,576	108,958	108,844

[1] Included with "Other."

PRICES

Magnesium metal prices increased incrementally during the calendar years 1978 and 1979 as follows:

Jan. 1 - Mar. 31, 1978	$0.99 per pound
Apr. 1, 1978 - Jan. 31, 1979	1.01 per pound
Feb. 1 - Sept. 30, 1979	1.055 per pound
Oct. 1 - Dec. 31, 1979	1.09 per pound

STOCKS

Producer and consumer stocks of primary magnesium totaled 12,583 short tons at yearend 1978 and 13,901 tons at yearend 1979. Stocks of primary alloy ingot at yearend 1978 were 884 tons and at yearend 1979, were 767 tons. New and old magnesium scrap stocks are shown in table 4.

Table 4.—Stocks and consumption of new and old magnesium scrap in the United States

(Short tons)

Item	Stocks Jan.1	Receipts	Consumption			Stocks Dec. 31
			New scrap	Old scrap	Total	
1978:						
Cast scrap	1,078	6,511	470	6,068	6,538	1,051
Solid wrought scrap[1]	129	576	609	--	609	96
Total	1,207	7,087	1,079	6,068	7,147	1,147
1979:						
Cast scrap	1,051	5,725	447	5,250	5,697	1,079
Solid wrought scrap[1]	[r]95	1,240	1,102	--	1,102	233
Total	1,146	6,965	1,549	5,250	6,799	1,312

[r] Revised.

[1] Includes borings, turnings, drosses, etc.

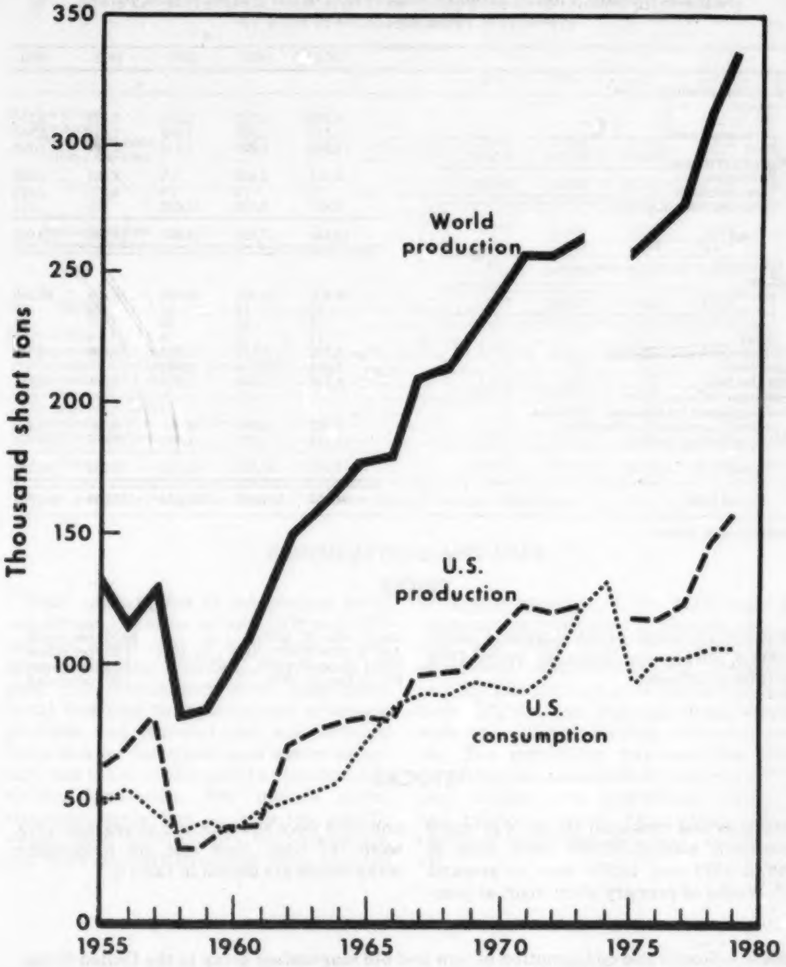

Figure 1.—U.S. and world production and U.S. consumption of primary magnesium.

FOREIGN TRADE

U.S. exports of magnesium metal were strong in 1978-79 and have increased from a low in 1976. Except for 1976, the United States has been a consistent net exporter of magnesium metal. Significant quantities of metal were exported to other industrialized nations.

Imports of magnesium metal were low during 1978-79 and accounted for only a small fraction of the domestic metal supply.

Table 5.—U.S. exports and imports for consumption of magnesium

Year	Exports					
	Waste and scrap		Metals and alloys in crude form		Semifabricated forms, n.e.c.	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1977	105	$136	26,309	$44,907	1,647	$6,805
1978	1,434	2,397	37,082	63,008	3,291	10,382
1979	688	794	47,451	90,788	6,136	22,246

Year	Imports							
	Waste and scrap		Metal		Alloys (magnesium content)		Powder, sheets, tubing, ribbons, wire, other forms (magnesium content)	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1977	3,829	$3,834	1,770	$2,850	299	$1,073	66	$219
1978	4,798	5,018	1,271	2,150	542	1,897	57	1,013
1979	2,757	2,958	1,460	3,127	412	1,767	125	1,190

Table 6.—U.S. exports of magnesium, by class and country

Destination	Waste and scrap		Primary metals alloys		Semifabricated forms, n.e.c., including powder	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1977						
Argentina	5	$7	491	$985	--	--
Australia	1	2	1,251	2,207	36	$303
Austria	--	--	--	--	13	44
Belgium-Luxembourg	2	3	--	--	33	199
Bolivia	4	1	14	17	--	--
Brazil	--	--	6,765	11,143	2	9
Canada	72	101	1,766	3,386	524	1,462
Colombia	--	--	29	73	4	15
France	--	--	2	4	32	144
Germany, Federal Republic of	--	--	2,748	4,735	425	1,981
Hong Kong	6	8	--	--	--	--
India	--	--	80	127	(1)	2
Israel	--	--	4	11	119	461
Italy	--	--	94	348	7	73
Japan	14	13	1,968	3,233	211	1,004
Korea, Republic of	--	--	--	--	18	139
Mexico	1	1	2,774	4,598	54	120
Netherlands	--	--	7,452	12,500	5	30
New Zealand	--	--	117	181	7	69
Norway	--	--	(1)	2	1	11
South Africa, Republic of	--	--	406	707	10	78
Spain	--	--	--	--	23	73
Sweden	--	--	--	--	34	277
Taiwan	--	--	60	93	1	1
United Kingdom	--	--	28	93	56	185
Venezuela	--	--	149	263	--	--
Others	--	--	111	201	32	136
Total	105	136	26,309	44,907	1,647	6,805
1978						
Argentina	--	--	71	144	2	15
Australia	18	51	1,381	2,374	110	962
Austria	--	--	27	28	23	49
Belgium-Luxembourg	80	161	92	145	135	694
Brazil	--	--	6,621	11,312	1,105	1,857
Canada	2	6	2,198	4,244	383	1,330

See footnotes at end of table.

Table 6.—U.S. exports of magnesium, by class and country —Continued

Destination	Waste and scrap		Primary metals alloys		Semifabricated forms, n.e.c.,including powder	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1978 —Continued						
China:						
Mainland	--	--	1,101	$1,689	--	--
Taiwan	82	$34	124	143	7	$15
Colombia	3	8	43	89	8	25
France	3	26	1	10	14	150
Germany, Federal Republic of	20	28	2,467	3,521	234	1,269
Ghana	--	--	--	--	225	410
Hong Kong	66	19	7	6	--	--
India	3	13	230	361	--	--
Israel	--	--	--	--	99	353
Italy	--	--	429	1,119	13	113
Japan	(1)	1	6,850	12,209	181	548
Korea, Republic of	97	34	273	350	12	139
Mexico	777	1,482	1,128	2,130	430	1,051
Netherlands	251	475	12,029	19,401	8	35
New Zealand	--	--	140	246	28	280
Norway	--	--	911	1,655	1	12
South Africa, Republic of	2	7	657	1,244	16	124
Spain	--	--	50	78	26	135
Sweden	--	--	10	42	6	53
United Kingdom	--	--	43	65	70	320
Venezuela	2	6	9	37	33	157
Others	28	46	190	366	122	286
Total	1,434	2,397	37,082	63,008	3,291	10,382
1979						
Argentina	--	--	470	932	76	261
Australia	56	163	678	1,171	743	2,734
Austria	--	--	--	--	267	598
Belgium-Luxembourg	--	--	83	145	557	1,738
Brazil	1	4	9,885	18,651	5	19
Cameroon	--	--	144	298	--	--
Canada	47	160	2,655	5,559	119	1,135
China:						
Mainland	--	--	5,118	8,282	--	--
Taiwan	15	21	--	--	2	6
Colombia	--	--	28	59	23	72
France	(1)	1	2	31	63	617
Germany, Federal Republic of	214	296	2,261	4,443	903	3,355
Ghana	--	--	1,001	1,861	--	--
Hong Kong	--	--	6	13	69	155
India	--	--	227	395	65	158
Israel	--	--	110	447	80	354
Italy	2	16	48	168	414	1,386
Japan	106	26	8,045	15,514	606	1,948
Korea, Republic of	242	84	199	352	164	1,22[illegible]
Mexico	--	--	1,572	3,122	181	878
Netherlands	--	--	13,188	25,171	1,232	2,604
New Zealand	--	--	89	169	11	140
Norway	--	--	232	738	6	24
Romania	--	--	434	876	12	31
Saudi Arabia	--	--	104	207	24	69
Singapore	--	--	190	732	1	7
South Africa, Republic of	--	--	590	1,169	65	292
Spain	--	--	15	62	60	255
Sweden	--	--	5	19	19	168
United Kingdom	1	12	26	75	116	629
Venezuela	1	1	2	4	57	327
Others	3	10	49	123	196	1,062
Total	688	794	47,456	90,788	6,136	22,246

[1] Less than 1/2 unit.

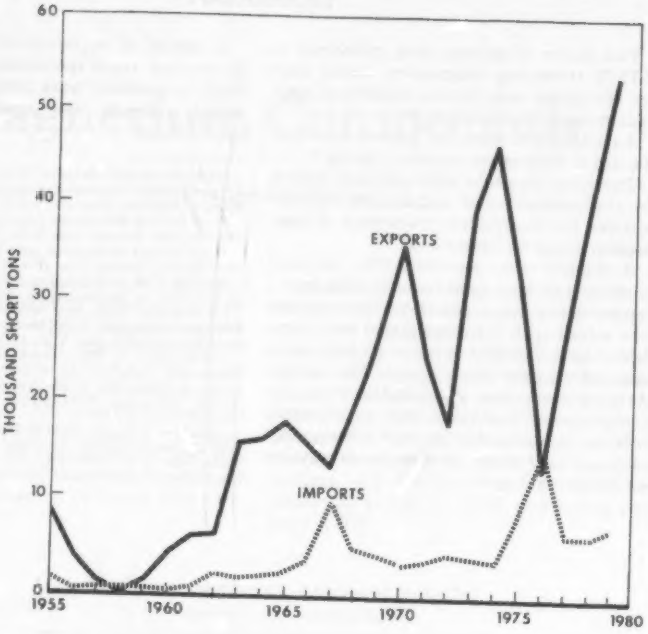

Figure 2. — U.S. imports and exports of magnesium.

WORLD REVIEW

Magnesium production has increased steadily since 1975 to meet world demand. The United States was the largest primary magnesium metal producer in 1978-79. Other producing countries are identified in table 7. World magnesium production is expected to continue to increase until all available installed production capacity is utilized.

Table 7.—Magnesium: World primary production, by country

(Short tons)

Country	1976	1977	1978[p]	1979[e]
Canada	6,715	8,414	9,160	[1]10,110
China, Mainland[e]	1,100	1,100	1,100	1,100
France	8,825	[r]9,571	9,370	10,000
India	33	118	25	50
Italy	9,740	9,663	10,688	9,500
Japan[2]	12,335	[r]10,379	12,308	[1]12,531
Norway	42,778	42,070	43,155	50,000
U.S.S.R.[e]	69,000	[r]71,000	77,000	79,000
United States[3]	119,957	125,058	149,462	[1]162,291
Total	[r]270,483	[r]277,373	312,263	334,582

[e]Estimate. [p]Preliminary. [r]Revised.

[1] Reported figure.

[2] Secondary production was as follows, in short tons: 1976-8,153; 1977-8,392; 1978-12,125; 1979-8,800.

[3] Derived figure; United States' production is not officially reported by the Bureau of Mines in order to avoid dislosing company proprietary data; figures reported represent the difference between total North American production reported by the International Magnesium Association and Canadian production reported by the Canadian Department of Mines and Natural Resources.

TECHNOLOGY

Two series of papers were published in 1978-79 reviewing magnesium metal market conditions and current aspects of magnesium metal technology.[2] [3]

An additional group of papers described the use of magnesium in steel-making.[4]

The principles of a solar ponding system for the production of magnesium chloride suitable for electrolytic production of magnesium metal was described.[5]

A method was described that supplied pure anhydrous magnesium chloride from a concentrated brine solution. The solution was mixed with ethylene glycol and dehydrated in a distillation tower to anhydrous magnesium chloride in glycol. The magnesium chloride was precipitated from the glycol under conditions that precipitated only magnesium chloride from solution. All reagents used in the process were recycled with minimal loss.[6]

A series of supercorroding magnesium alloys that react spontaneously and vigorously in seawater were developed for use as timed releases for ocean engineering applications.[7]

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[1] Physical scientist, Section of Nonferrous Metals.

[2] International Magnesium Association. Proc., 35th Ann. Meeting, Spokane, Wash., June 25-27, 1978, 62 pp.

[3] International Magnesium Association. Proc., 36th Ann. Meeting, Oslo, Norway, June 24-28, 1979, 70 pp.

[4] International Magnesium Association, Magnesium in Steel Making. Dayton, Ohio, 1979, 62 pp.

[5] Barlow, E. W., S. C. Johnson, and A. Sedan. Solar Ponds as a Source of Magnesium for Electrolytic Cells. Proc. Tech. Sessions, 109th Ann. Meeting, AIME, Feb. 24-28, 1980, Las Vegas, Nev. Light Metals Committee, Metallurgical Society, AIME, New York, 1979, pp. 913-927.

[6] Allain, R. J. A New Process for Making Anhydrous Magnesium Chloride. Proc. of Tech. Sessions, 109th Ann. Meeting, AIME, Feb. 24-28, 1980, Las Vegas, Nev. Light Metals Committee, Metallurgical Society, AIME, New York, 1979, pp. 929-946.

[7] Black, S. A. Development of Supercorroding Alloys for Use as Timed Releases for Ocean Engineering Applications. Rept. No. CEL-TN-1550, Civil Engineering Lab. (U.S. Navy), Port Hueneme, Calif., Mar. 1979, 40 pp.

Magnesium Compounds

By Benjamin Petkof[1]

The United States retained its place as a major world producer of magnesium compounds in 1978 and 1979. Domestic output was based chiefly on the production of magnesia from natural brines. The total quantities of magnesium compounds shipped and used in 1978 and 1979 increased over those of 1977. Total exports of magnesite and magnesia increased in 1978 and 1979 over those of 1977, and total imports of magnesite increased in 1978 and 1979 over those of 1977.

Austria, Greece, Mainland China, North Korea, and the U.S.S.R. were major world sources of magnesite.

Legislation and Government Programs.—New tariff rates resulted for some classes of magnesium compounds from the 1979 Tokyo Round of tariff negotiations giving most nations "most-favored-nation" status. The tariffs for material from these nations will decline annually, in stages, beginning January 1, 1980, and ending January 1, 1987.

Table 1.—Salient magnesium compound statistics

(Thousand short tons and thousand dollars)

	1975	1976	1977	1978	1979
United States:					
Caustic-calcined and specified magnesias:[1]					
Shipments by producers:					
Quantity	120	134	129	156	164
Value	$17,207	$28,277	$29,574	$43,008	$50,047
Exports: Value[2]	$4,538	$5,422	$6,336	$7,741	$16,433
Imports for consumption: Value[2]	$502	$808	$566	$793	$1,169
Refractory magnesia:					
Sold and used by producers:					
Quantity	709	768	690	796	847
Value	$103,839	$106.522	$94,799	$125,062	$125,289
Exports: Value	$14,146	$13,466	$16,477	$10,617	$8,182
Imports: Value	$20,588	$13,976	$12,332	$14,421	$13,546
Dead-burned dolomite:					
Sold and used by producers:					
Quantity	914	1,007	968	1,016	793
Value	$31,193	$37,079	$37,992	$45,881	$41,676
World: Crude magnesite production: Quantity	[r]10,614	[r]9,933	[r]10,706	10,704	11,086

[r] Revised.

[1] Excludes caustic-calcined magnesia used in production of refractory magnesia.

[2] Caustic-calcined magnesia only.

DOMESTIC PRODUCTION

Natural brine solutions, from seawater, lakes, and wells, continued to be the primary source of domestically produced magnesium compounds. Natural magnesite and olivine were produced at a few operations in the United States. Natural magnesite was also converted to magnesium compounds. Olivine was comminuted to various grades for foundry use.

The Velsicol Chemical Corp. discontinued magnesium compound operations as of September 1978.

Most of the firms that produced magnesium hydroxide also produced other magnesium compounds. Current domestic magnesium compounds producers by raw material source, location, and capacity follow:

Raw material source and producing company	Location	Capacity (short tons of MgO equivalent)
Magnesite: Basic, Inc	Gabbs, Nev	150,000
Lake brines:		
Great Salt Lake Minerals & Chemicals Corp	Ogden, Utah	100,000
Kaiser Aluminum & Chemical Corp	Wendover, Utah	50,000
Well brines:		
The Dow Chemical Co	Ludington, Mich	300,000
The Dow Chemical Co	Midland, Mich	75,000
Martin Marietta Chemicals	Manistee, Mich	300,000
Velsicol Chemical Corp.[1]	St. Louis, Mich	25,000
Morton Chemical Co	Manistee, Mich	5,000
Seawater:		
Barcroft Co	Lewes, Del	5,000
Basic Magnesia, Inc	Port St. Joe, Fla	100,000
Corning Glass Works, Ceramic Products Division	Pascagoula, Miss	40,000
The Dow Chemical Co	Freeport, Tex	75,000
Harbison-Walker Refractories Co	Cape May, N.J	100,000
Kaiser Aluminum & Chemical Corp	Moss Landing, Calif	150,000
Merck & Co., Inc	South San Francisco, Calif	15,000
Western Magnesium Corp	Chula Vista, Calif	5,000
Total		[2]1,470,000

[1] MgO production discontinued in September 1978.
[2] Production capacity of Velsicol Chemical Corp. not included in total.

CONSUMPTION AND USES

Domestic demand for magnesium compounds was strong during 1978 and 1979 and above that of 1977. The manufacture of refractory products continued to be the major end use for magnesium compounds. Caustic-calcined and specified magnesias also remained in strong demand by the chemical processing and pharmaceutical industries. Some major uses for caustic-calcined and specified magnesias were in the manufacture of animal feeds, fertilizers, construction materials, chemicals, electrical heating rods, fluxes, petroleum additives, rayon, and uranium.

Table 2.—Magnesium compounds shipped and used in the United States

	1978		1979	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Caustic-calcined[1] and specified (USP and technical) magnesias	156,192	$43,008	163,565	$50,047
Refractory magnesia	795,596	125,082	846,612	125,289
Magnesium hydroxide (100% $Mg(OH)_2$)[1]	509,824	40,520	511,370	47,475
Magnesium sulfate (anhydrous and hydrous)	52,096	11,885	48,325	10,271
Precipitated magnesium carbonate[1]	3,935	1,131	4,020	1,224

[1] Excludes material produced as an intermediate step in the manufacture of other magnesium compounds.

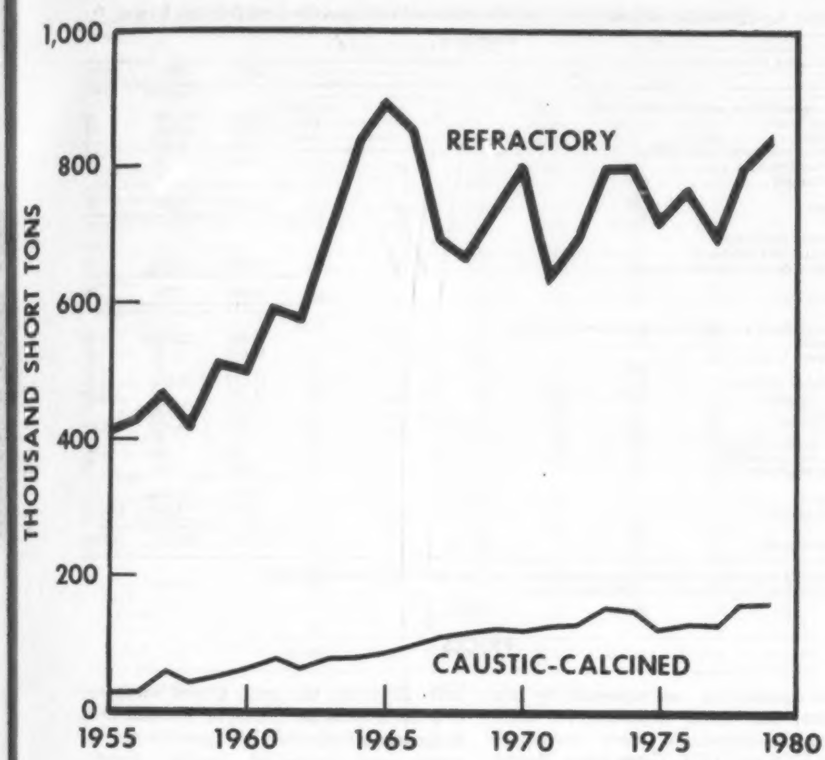

Figure 1.—Consumption and shipments of magnesia in the United States.

Table 3.—Domestic shipments of caustic-calcined and specified magnesias, by use

(Short tons)

Use	1977	1978	1979
Agriculture, nutrition, and pharmaceuticals:			
Animal feed	26,518	35,776	W
Fertilizer	10,379	16,506	W
Medicinals and pharmaceuticals	689	1,923	701
Sugar and candy	3,886	W	W
Winemaking	--	W	--
Total	41,472	54,205	W
Construction materials:			
Insulation and wallboard	(1)	(1)	W
Oxychloride and oxysulfate cement	10,889	3,753	W
Total	10,889	3,753	W
Chemical processing, manufacturing, and metallurgical:			
Chemical	7,935	12,070	W
Electrical heating rods	11,650	W	W
Flux	W	W	W
Petroleum additive	11,912	20,652	W
Pulp and paper	15,933	W	W
Rayon	9,785	W	W
Rubber	11,677	12,568	14,209
Stack gas scrubbing	--	W	W
Uranium processing	W	W	W
Water treatment	3,089	3,404	W
Total	71,981	48,694	95,534
Unspecified uses	4,504	49,540	148,684
Grand total	128,846	156,192	163,594

W Withheld to avoid disclosing company proprietary data; included with "Unspecified uses."
[1] Included with "Oxychloride and oxysulfate cement."

PRICES

Price quotations, as reported by the Chemical Marketing Reporter, for some magnesium compounds were unchanged during 1978 and 1979. These were: Magnesia, natural, technical, heavy, 85% and 90% (bulk, carlot and truckload, f.o.b. Nevada), $120 and $140 per short ton, respectively; and magnesium chloride, hydrous, 99%, flake (bags, carlot, works), $140 per ton. Quotations for other magnesium compounds increased during the 2-year period. Magnesia, technical, neoprene-grade, light (bags, carlot and truckload, works) was quoted at $346 per ton during 1978. Magnesium carbonate, technical (bags, carlot and truckload, works, freight-equalized) was quoted at $0.22 to $0.23 per pound during 1978. However, the price quoted increased to $0.52 to $0.54 per pound by yearend 1979. Magnesium hydroxide, NF, powder (drums, carlot and truckload, works, freight-equalized) was quoted as follows: At the beginning of 1978, $0.35 to $0.36 per pound; at the end of 1978, $0.49 to $0.53 per pound; and at the end of 1979, $0.54 to $0.58 per pound. Magnesium sulfate, technical (bags, mixed carlot, 10,000-pound minimum, works), was quoted at $0.091 per pound at the beginning of 1978. At the end of both 1978 and 1979 the price was quoted at $0.121 per pound. The price quotation for magnesium sulfate in bulk was $0.006 less per pound.

FOREIGN TRADE

Significant quantities of magnesium materials such as deadburned magnesite and magnesia and crude caustic-calcined lump or ground magnesite were exported. Large quantities of these magnesium commodities were supplied to Canada, Mexico, the United Kingdom, and Venezuela.

Total imports of crude and processed magnesite were under 100,000 tons and valued under $20 million in both years. The United States also imported additional magnesium compounds valued at $3.06 million in 1977, $4.6 million in 1978, and $5.62 million in 1979.

Table 4.—U.S. exports of magnesite and magnesia, by country

Destination	Magnesite and magnesia, dead-burned				Magnesite, n.e.c., including crude caustic-calcined, lump or ground			
	1978		1979		1978		1979	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Argentina	6	$8	26	$18	52	$44	4,887	$1,314
Australia	--	--	225	152	833	600	683	585
Belgium-Luxembourg	--	--	--	--	81	19	1,187	281
Brazil	83	78	105	79	42	31	33	30
Canada	50,708	7,704	26,053	5,929	34,057	2,462	51,238	8,869
Chile	--	--	--	--	51	25	113	48
Colombia	15	16	1,466	170	38	37	64	60
Dominican Republic	776	148	649	112	3	3	3	4
Ecuador	--	--	--	--	11	11	96	22
France	2,058	488	87	20	305	190	1,078	431
Germany, Federal Republic of	6,216	1,499	3	3	419	256	593	402
Guatemala	--	--	--	--	73	15	40	26
Guyana	--	--	360	30	--	--	--	--
Italy	41	35	21	18	248	197	587	362
Jamaica	54	8	--	--	2	3	--	--
Japan	196	142	36	33	203	210	157	187
Korea, Republic of	--	--	42	39	61	56	78	77
Mexico	160	40	1,114	273	3,456	517	711	166
Netherlands	214	54	286	85	333	531	327	591
New Zealand	--	--	20	24	67	64	149	148
Peru	--	--	8	2	120	28	8	13
Poland	--	--	--	--	757	200	--	--
Singapore	--	--	410	106	3	4	11	5
South Africa, Republic of	114	100	104	102	240	103	87	60
Spain	--	--	22	9	117	42	94	38
Sweden	77	72	43	51	241	237	194	210
Taiwan	57	49	73	71	142	54	203	85
United Kingdom	139	134	100	101	1,355	764	675	532
U.S.S.R.	--	--	--	--	--	--	1,102	336
Venezuela	--	--	1,716	724	2,845	900	3,824	1,414
Other	90	42	116	30	198	138	153	137
Total	61,004	10,617	33,035	8,183	46,353	7,741	68,375	16,433

[1] Less than 1/2 unit.

Table 5.—U.S. imports for consumption of crude and processed magnesite, by country

Country	1978 Quantity (short tons)	1978 Value (thousands)	1979 Quantity (short tons)	1979 Value (thousands)
Lump or ground caustic-calcined magnesia:[1]				
Australia	1,593	$260	1,063	$221
Germany, Federal Republic of	2	1	25	6
Greece	1,102	160	3,732	628
India	4,325	333	428	39
Netherlands	202	39	114	26
Turkey	--	--	1,123	249
Total	7,224	793	6,485	1,169
Dead-burned and grain magnesia and periclase:				
Not containing lime or not over 4% lime:				
Austria	72	29	--	--
Brasil	--	--	6,283	867
Canada	45	6	--	--
France	--	--	(2)	3
Germany, Federal Republic of	8	3	(2)	(2)
Greece	14,669	2,692	9,095	2,209
Ireland	43,747	8,441	24,183	4,809
Israel	1,093	274	2,330	617
Japan	15,920	2,976	23,171	5,041
Total	75,554	14,421	65,062	13,546
Containing over 4% lime:				
Canada	999	51	1,424	163
Germany, Federal Republic of	152	36	341	90
Greece	4,449	432	--	--
Ireland	6,250	1,188	24,572	4,727
Mexico	57	3	1,527	54
United Kingdom	--	--	1	(2)
Total	11,907	1,710	27,865	5,034
Total dead-burned and grain magnesia and periclase	87,461	16,131	92,927	18,580

[1] In addition, crude magnesite was imported as follows: 1978—India 6 short tons ($300), Mexico 46 short tons ($2,374); 1979—Canada 96 short tons ($3,771), India 11 short tons ($800), and Japan 2 short tons ($801).

[2] Less than 1/2 unit.

Table 6.—U.S. imports for consumption of magnesium compounds

Year	Oxide or calcined magnesia: Quantity (short tons)	Oxide or calcined magnesia: Value (thousands)	Magnesium carbonate[1] (precipitated): Quantity (short tons)	Magnesium carbonate[1] (precipitated): Value (thousands)	Magnesium chloride (anhydrous): Quantity (short tons)	Magnesium chloride (anhydrous): Value (thousands)	Magnesium chloride (other): Quantity (short tons)	Magnesium chloride (other): Value (thousands)	Magnesium sulfate (epsom salts and kieserite): Quantity (short tons)	Magnesium sulfate (epsom salts and kieserite): Value (thousands)	Magnesium salts and compounds n.s.p.f.[2]: Quantity (short tons)	Magnesium salts and compounds n.s.p.f.[2]: Value (thousands)
1977	420	$536	67	$117	53	$26	90	$14	36,100	$1,388	5,115	$976
1978	705	795	80	149	48	12	215	55	28,984	1,650	7,892	1,203
1979	3,216	1,772	95	187	26	15	164	73	25,950	1,530	6,988	2,042

[1] In addition, magnesium carbonate not precipitated, was imported as follows: 1977— 33 short tons ($29,064); 1978— 65 short tons ($39,824); 1979—32 short tons ($24,942).

[2] Not specifically provided for; includes magnesium silicofloride or fluosilicate and calcined magnesium.

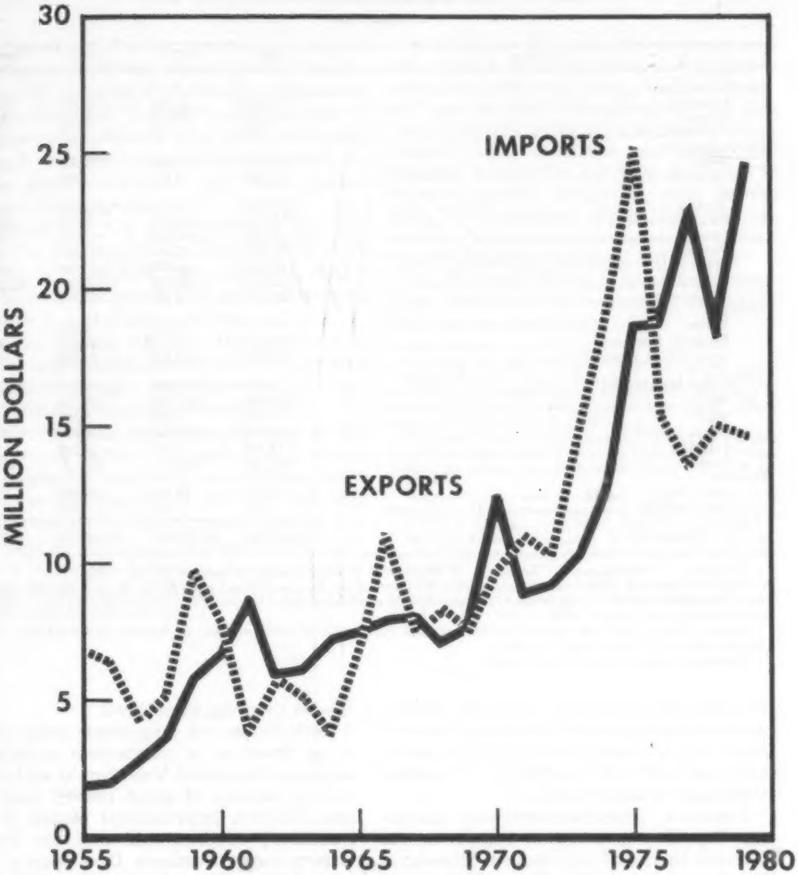

Figure 2.—Value of U.S. exports and imports of magnesia.

WORLD REVIEW

Australia.—Magnesite was mined in New South Wales by Fifield Magnesite and Refractory Pty. The company was acquired in 1977 by Harbison-ACI, a joint subsidiary of Harbison-Walker Refractories and Australian Consolidated Industries. Major investments were made in new mining and processing equipment for the Fifield plant to produce about 15,000 tons per year of deadburned magnesite, primarily for consumption in Harbison-ACI's refractories plant at Unanderra. The Young Mining Co. Pty. also produced magnesite and was being expanded to increase production of caustic-calcined magnesia and light and heavy magnesium carbonate.

Canada.—A pilot plant, in Quebec City, established by the Ministry of Natural Resources of Quebec, recovered magnesium compounds from asbestos tailings. The asbestos tailings were treated with hydrochloric acid to convert magnesium compounds

Table 7.—Magnesite: World production, by country[1]

(Short tons)

Country	1976	1977	1978[p]	1979[e]
North America:				
Canada[e]	26,000	41,000	39,000	58,000
Mexico	25,558	73,193	83,814	84,000
United States	W	W	W	W
South America:				
Brazil[2]	215,917	226,766	239,500	239,000
Colombia	[r]1,909	1,951	1,543	1,500
Europe:				
Austria	1,021,334	1,105,662	1,082,821	1,100,000
Czechoslovakia	[r]720,911	728,627	724,218	730,000
Greece	1,415,730	1,146,903	908,421	850,000
Poland	[r]28,990	27,000	[e]27,000	28,000
Spain	[r]383,694	464,338	[e]450,000	500,000
U.S.S.R.[e]	1,980,000	2,040,000	2,090,000	2,150,000
Yugoslavia	431,003	380,297	367,069	327,000
Africa:				
Kenya	3	3,941	[e]4,000	4,100
Rhodesia, Southern[e]	22,000	22,000	46,300	46,300
South Africa, Republic of	69,289	54,255	41,234	44,000
Asia:				
China, Mainland[e]	1,100,000	[r]1,700,000	2,000,000	2,200,000
India	[r]363,429	443,136	462,575	470,000
Iran[3]	5,500	5,500	5,500	--
Korea, North[e]	1,650,000	1,650,000	1,650,000	1,650,000
Pakistan	[r]3,578	1,724	2,945	3,000
Turkey	[r]451,149	568,971	459,885	580,000
Oceania:				
Australia	[r]16,211	20,426	[e]22,000	20,000
New Zealand	887	614	925	950
Total	[r]9,933,092	10,706,304	10,703,750	11,085,850

[e] Estimate. [p] Preliminary. [r] Revised. W Withheld to avoid disclosing company proprietary data.

[1] Figures represent crude salable magnesite. In addition to the countries listed, Bulgaria and Canada produce magnesite, but output is not reported quantitatively and available general information is inadequate for formulation of reliable estimates of output levels.

[2] Series reflects output of marketable concentrates. Production of crude ore was as follows: 1976—414,612; 1977—481,154; 1978—[e]510,000; 1979—[e]510,000.

[3] Year beginning March 21 of that stated.

to magnesium chloride. This was further processed to magnesium oxide with regeneration of hydrochloric acid. The process is operated under wet conditions, eliminating the danger of asbestos dust.

India.—A 20-million-metric-ton magnesite deposit was found in Bagolis in the Chanoli district of the Gashwal Himalayas by personnel from the Wadia Institute of Himalayan Studies.

Nepal.—The Department of Mines and Geology and M/s Orissa Industries Ltd. of Rourkela, Orissa, India, have signed an agreement to develop and operate the Kharidhunga magnesite deposit to produce about 55,000 tons of deadburned magnesia at Lamosangu and 22,000 tons per year of basic refractory brick at Birgunj. A long-term loan for the project was to be arranged by the company and guaranteed by the Government of Nepal. The Kharidhunga deposit was estimated to contain almost 200 million tons, of magnesite of which about 73 million tons were considered refractory grade. The geographic area and depth of the deposit were also established.

Netherlands.—A magnesium oxide plant using brine as a magnesium compound source is planned at Veendam by mid-1981, with a capacity of about 100,000 tons per year. Billiton International Metals B. V. (subsidiary of Shell Oil) and the Dutch Government's Northern Development Co. have underwritten the plant for $100 million.

Turkey.—There were four major magnesite producers in the country: Kutahya Manyezit Isletmeleri AS (Kumas), Manyezit AS, Sumerbank, and Continental Madencilik Sanayi ve Ticaret AS (Comag). Kumas, Manyezit, and Sumerbank produced deadburned magnesite. Comag produced caustic-calcined magnesite. The deadburned magnesite producers had a production capacity of about 375,000 tons per year; and the caustic-calcined producer, about 33,000 tons per year. None of these companies operated at full capacity, but they did mine and process their own raw material.

TECHNOLOGY

The effects of water vapor on the magnesia sintering process were studied by measuring the isothermal shrinkage at temperatures from 900° to 1,200°C as a function of water vapor pressure from 0.002 to 189 mm Hg. It was observed that magnesia sintering was greatly improved with higher water vapor pressure.[2]

Construction of a modified slag test furnace to simulate basic oxygen furnace corrosion was reported. The installation used a coke bed to control furnace atmosphere, establish a thermal gradient, and provide for ease of slag removal. The furnace was used to determine the effect of various slag compositions on the corrosion of tar-impregnated magnesia refractories.[3]

The effects of reducing conditions on the high-temperature strength of pitch-impregnated magnesia refractories were discussed. It was found that the chemical composition of the brick, especially the ratio of CaO to SiO_2 and the quantity of CaO, were important factors in the retention of high-temperature strength when measured under reducing conditions.[4]

A technique for qualitative evaluation of the thermal shock resistance of magnesia refractory brick was developed. The chance for crack formation behind a hot brick face was calculated using experimentally determined physical properties and the thermal gradient behind the hot face of the brick. Needed physical properties, such as the critical deformation under load and the critical deformation in tension, were determined for burned magnesia refractories.[5]

An improved method of preparing magnesium oxychloride or magnesium oxysulfate cements was described.[6]

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[1] Physical scientist, Section of Nonferrous metals.

[2] Hamano, K., K. Asano, Y. Akiyama, and Z. E. Nakagawa. Effects of Water Vapor Pressure on Sintering of Magnesia. Report of the Res. Lab. of Eng. Mater., Tokyo Inst. of Technol., 1979, pp. 59-68.

[3] Tompkins, T. L., R. A. Howe, and T. D. McGee. Furnace for Testing Refractory Corrosion By Basic Oxygen Furnace Slags. Am. Ceram. Soc. Bull., v. 58, No. 7, July 1979, pp. 710-714.

[4] Shultz, R. L., and B. Brezny. High Temperature Strength of MgO Refractories Under Reducing Conditions. Am. Ceram. Soc. Bull., v 58, No. 7, July 1979, pp. 683-686.

[5] Brezny, B. Crack Formation in BOF Refractories During Gunning. Am. Ceram. Soc. Bull., v. 58, No. 7, July 1979, pp. 679-682.

[6] Irwin, R. G. (assigned to PPG Industries). Preparing Magnesium Oxychloride and/or Oxysulfate Cements. U.S. Pat. 4,158,570, June 19, 1979.

Manganese

By Gilbert L. DeHuff[1]

No manganese ore containing 35% or more manganese was produced in the United States in either 1979 or 1978. Some manganiferous ores of lower manganese content, however, were produced and shipped in Minnesota, New Mexico, and South Carolina both years. Both imports of ore and production of ferromanganese fell to low levels, although 1979 ferromanganese production recovered somewhat from that of 1978. Perhaps the most noteworthy development during the 2-year period was the acquisition of U.S. manganese ferroalloy producers by foreign firms: Airco Inc. going first to British Oxygen and later part to Autlán of Mexico and part to the Federal Republic of Germany firm, SKW Trostberg; Roane Electric Furnace Co. went to the large South African manganese ore producer, SAMANCOR; and Chemetals Division of Diamond Shamrock, to Sedema of Belgium. Imports of manganese ferroalloys from developing countries were benefitted by the tariff suspensions granted them by the General System of Preferences and ferromanganese imports increased each year to establish new records. Deliveries of ore continued to be made by the General Services Administration from Government stockpile excesses.

Legislation and Government Programs.—Sales of Government manganese stockpile excesses consisted of 257,130 short tons in 1978 and 3,338 tons in 1979 of nonstockpile-grade metallurgical ore, plus 200 tons of stockpile-grade natural battery ore in 1979. An earlier sale of 50,440 tons of specification-grade metallurgical ore was canceled in January 1978.

Changes over the 2-year period in manganese items in Government stockpile physical inventories were as follows (short tons gross weight): Stockpile-grade natural battery ore decreased 24,186 tons to 206,789 tons; stockpile-grade metallurgical ore decreased 1,199,754 tons to 3,046,954 tons; and nonstockpile-grade metallurgical ore decreased 15,219 tons to 1,235,626 tons. The following items remained unchanged except for minor inventory adjustments: Nonstockpile-grade natural battery ore at 54,899 tons; synthetic manganese dioxide, 3,011 tons; chemical ore, 220,829 tons; high-carbon ferromanganese, 599,764 tons; medium-carbon ferromanganese, 28,921 tons; silicomanganese, 23,574 tons; and electrolytic metal, 14,171 tons. Both inventories for metallurgical ore at the end of 1979 included material sold under long-term contract but not yet shipped.

The Department of Labor determined in 1978 that 125 employees of Roane Electric

Table 1.—Salient manganese statistics in the United States

(Short tons)

	1975	1976	1977	1978	1979
Manganese ore (35% or more Mn):					
Imports, general	1,574,045	1,316,812	930,947	547,820	499,782
Consumption	1,818,983	1,600,873	1,358,811	1,281,479	1,372,190
Manganiferous ore (5% to 35% Mn):					
Production (shipments)	159,225	256,633	215,893	312,124	240,696
Ferromanganese:					
Production	575,809	482,662	334,134	272,530	317,102
Exports	32,300	6,789	6,051	9,433	25,344
Imports for consumption	397,212	537,409	534,423	680,399	821,213
Consumption	881,527	896,775	886,299	985,623	976,482

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Furnace Co. engaged in silicomanganese production at Rockwood, Tenn., and 100 employees of Ohio Ferro-Alloys Corp. producing manganese ferroalloys at Philo, Ohio, were eligible to apply for trade adjustment assistance because their jobs were threatened or lost by rising imports. Available trade adjustment assistance includes job training, cash grants, and employment services.

The Environmental Protection Agency banned the use of methylcyclopentadienyl manganese tricarbonyl (MMT) as a gasoline additive, with enforcement effective as of October 27, 1978. In June 1979, in the interest of increasing the supply of unleaded gasoline, enforcement of the ban was suspended through September 30. It was estimated that this would add 340,000 barrels per day to the summer's unleaded gasoline supply.

DOMESTIC PRODUCTION

No manganese ore, concentrate, or nodules, containing 35% or more manganese, was produced or shipped in the United States in either 1978 or 1979. Ferruginous manganese ores or concentrates containing 10% to 35% manganese continued to be produced and shipped both years in New Mexico and on the Cuyuna Range of Minnesota. Manganiferous schist, clay, or other earthy material associated with the manganiferous member of the Battleground schist of the Kings Mountain area also continued to be mined in Cherokee County, S.C., by brick manufacturers or contractors for use in coloring brick. The material reported in table 2 ranged in manganese content from 5% to 15%, but averaged less than 10%.

Table 2.—Manganese and manganiferous ore shipped[1] in the United States, by State

(Short tons)

Type and State	1978 Gross weight	1978 Manganese content	1979 Gross weight	1979 Manganese content
Manganese ore (35% or more Mn, natural)	--	--	--	--
Manganiferous ore:				
Ferruginous manganese ore (10% to 35% Mn, natural):				
Minnesota	253,399	32,891	181,503	25,579
New Mexico	36,443	3,826	33,152	3,315
Total	289,842	36,717	214,655	28,894
Manganiferous iron ore (5% to 10% Mn, natural):				
South Carolina[2]	22,282	1,559	26,041	1,969
Total	22,282	1,559	26,041	1,969
Total manganiferous ore	312,124	38,276	240,696	30,863
Value of manganese and manganiferous ore	$3,073,827	XX	$2,902,233	XX

XX Not applicable.

[1] Shipments are used as the measure of manganese production for compiling U.S. mineral production value. They are taken at the point at which the material is considered to be in marketable form for the consumer. Besides direct-shipping ore, they include, without duplication, concentrate and nodules made from domestic ores.

[2] Miscellaneous ore.

CONSUMPTION, USES, AND STOCKS

In the production of raw steel (ingots, continuous- or pressure-cast blooms, billets, slabs, etc., and including steel castings), consumption of manganese as ferroalloys, metal, and direct-charged ore, as reported to the Bureau of Mines by consumers, was 12.7 pounds per short ton raw steel produced in 1979. Of this total, 11.0 pounds was contained in ferromanganese; 1.5 pounds, silicomanganese; negligible spiegeleisen; 0.2 pound, metal; and 0.01 pound, manganese ore (containing 35% or more manganese). The comparable 1978 total, on the same basis, was 12.5 pounds with ferromanganese at 10.9, silicomanganese at 1.4, spiegeleisen at 0.01, metal at 0.2, and ore at 0.01. In

Table 3.—Consumption and industry stocks of manganese ore[1] in the United States

(Short tons)

	Consumption		Stocks Dec. 31	
	1978	1979	1978	1979
By use:				
Manganese alloys and metal	832,179	913,491	774,622	706,148
Pig iron and steel	219,663	230,742	128,742	142,768
Dry cells, chemicals and miscellaneous	229,637	227,957	269,957	248,941
Total	1,281,479	1,372,190	1,173,051	1,097,857
By origin:				
Domestic	106,900	144,404	70,980	108,979
Foreign	1,174,579	1,227,786	1,102,071	988,878
Total	1,281,479	1,372,190	1,173,051	1,097,857

[1] Containing 35% or more manganese (natural).

Table 4.—Consumption, by end use, and industry stocks of manganese ferroalloys and metal in the United States in 1978-79

(Short tons, gross weight)

End use	Ferromanganese		Silico-manganese	Spiegel-eisen	Man-ganese metal[1]
	High carbon	Medium and low carbon			
1978					
Steel:					
Carbon	654,451	119,334	94,444	4,014	8,242
Stainless and heat-resisting	13,338	1,341	7,527	--	2,580
Full alloy	81,032	17,421	28,790	22	1,530
High-strength low-alloy	56,361	11,818	9,705	--	1,379
Electric	--	156	482	--	10
Tool	699	70	63	--	120
Unspecified	462	431	2,603	--	--
Total steel	806,343	150,571	143,614	4,036	13,861
Cast irons	22,437	1,474	16,365	--	61
Superalloys	257	22	W	--	197
Alloys (excludes alloy steels and superalloys)	2,076	1,122	2,598	--	13,213
Miscellaneous and unspecified	401	920	1,731	--	902
Total consumption	831,514	154,109	164,308	4,036	28,234
Stocks, Dec. 31:					
Consumer	162,254	17,191	17,012	W	4,029
Producer	33,591	24,009	24,381	W	2,709
Total stocks	195,845	41,200	41,393	61	6,738
1979					
Steel:					
Carbon	630,354	118,869	95,190	489	7,415
Stainless and heat-resisting	14,281	1,629	8,358	--	2,845
Full alloy	94,141	17,853	35,472	--	1,182
High-strength low-alloy	59,135	12,644	9,157	--	1,429
Electric	1	138	104	--	5
Tool	800	52	46	--	139
Unspecified	602	580	3,179	--	10
Total steel	799,264	151,765	151,506	489	13,025
Cast irons	20,220	1,260	15,716	--	14
Superalloys	247	W	--	--	236
Alloys (excludes alloy steels and superalloys)	1,887	478	2,386	--	13,938
Miscellaneous and unspecified	504	857	2,293	--	904
Total consumption	822,122	154,360	171,901	489	28,117
Stocks, Dec. 31:					
Consumer	151,493	20,225	18,358	W	3,891
Producer	29,812	23,795	21,243	W	2,614
Total stocks	181,305	44,020	39,601	35	6,505

W Withheld to avoid disclosing company proprietary data, included in "Miscellaneous and unspecified" where applicable.

[1] Virtually all electrolytic.

Table 5.—Ferromanganese and silicomanganese produced in the United States and manganese ore[1] consumed in their manufacture

Year	Production				Manganese ore[1] consumed (gross weight, short tons)		
	Ferromanganese						
	Gross weight (short tons)	Manganese content		Silicomanganese (gross weight, short tons)	Foreign[2]	Domestic[2]	Per ton of ferromanganese and silicomanganese made[3]
		Percent	Short tons				
1975	575,809	78.9	454,309	143,000	1,389,300	48,011	1.9
1976	482,662	79.0	381,328	129,000	1,208,336	53,632	2.0
1977	334,134	78.8	263,136	120,000	889,296	35,769	1.9
1978	272,530	80.6	219,707	142,000	740,906	90,660	1.9
1979	317,102	80.2	254,389	165,000	785,664	125,130	1.8

[1] Containing 35% or more manganese (natural).
[2] Includes ore used in producing silicomanganese and metal.
[3] Ratio of ore consumed to ferromanganese produced if silicomanganese is considered a special grade of ferromanganese. Includes ore used in producing silicomanganese.

addition to the aforementioned consumption of manganese in both 1979 and 1978, there was consumed per ton of raw steel produced approximately 1.4 pounds of manganese contained in manganese ore used in making pig iron or equivalent hot metal. The comparable figures for 1977 and 1976 were 1.3 and 1.0 pounds, respectively.

Rising costs, particularly power costs, and competition from imported material continued to trouble the domestic manganese ferroalloy producers and there was considerable restructuring of the electric furnace segment of the industry in 1979. Airco Inc., since the spring of 1978 a wholly owned subsidiary of BOC International Ltd., London, sold its Theodore (Mobile), Ala., plant in February 1979 to Mexico's principal producer of manganese ore and ferromanganese, Cia. Minera Autlán. Following in July, Airco's Calvert City, Ky., and Niagara Falls, N.Y., plants were sold to SKW Alloys, Inc., a wholly owned subsidiary of SKW Trostberg, AG, of Trostberg, Federal Republic of Germany. In September 1979, Engelhard Minerals & Chemicals Corp. sold the Roane Electric Furnace Co. and that division's Rockwood, Tenn., plant to Roane Ltd., a subsidiary of South African Manganese Amcor Ltd. (SAMANCOR). The latter is the largest producer of manganese ore in the Republic of South Africa.

Electrolytic Manganese Metal.—All of the manganese metal produced domestically and virtually all of that imported was electrolytic metal. Virtually all of the metal consumed was electrolytic metal, although some low-carbon ferromanganese (such as the domestically produced "Massive Manganese" or the imported "Gimel Metal") and some manganese-aluminum additives may have been erroneously reported by consumers as manganese metal. The metal that was used to make manganese-aluminum additives is included in table 4 under the "Alloys (excludes alloy steels and superalloys)" category. These additives are not knowingly included in the table, it being desired to report consumption at the metal rather than the additive level of the usage cycle.

Production of electrolytic manganese metal increased to 27,690 short tons in 1979 from 23,260 tons in 1978. Production continued to be by the same three plants of the same three companies: Foote Mineral Co., New Johnsonville, Tenn.; Kerr-McGee Chemical Corp., Hamilton (Aberdeen), Miss.; and Union Carbide Corp., Marietta, Ohio. In July 1979, Union Carbide Corp. completed an expansion and modernization of its electrolytic manganese metal production facilities at Marietta, thereby expecting to increase annual productive capacity by 1,000 to 1,500 tons.

Ferromanganese.—There was no domestic production of ferromanganese in blast furnaces in either 1979 or 1978. Electric furnaces were used to produce ferromanganese for shipment by five companies in six plants in 1978: Airco Alloys Div., Airco Inc., Calvert City, Ky.; Ohio Ferro-Alloys Corp., Philo, Ohio; Roane Electric Furnace Co. (Engelhard Minerals & Chemicals Corp.), Rockwood, Tenn.; Satralloy Inc. Div., Satra Corp., Steubenville, Ohio; and Union Carbide Corp., Marietta, Ohio, and Portland, Oreg. The same six plants produced for shipment in 1979 plus the Alloy, W.Va., plant of Union Carbide Corp. Fused-salt electrolysis continued to be the method used at Kingwood, W.Va., to make low-carbon ferromanganese sold under the trade name of Massive Manganese. Production continued as the Chemetals Division of Diamond Shamrock Corp. until June 9, 1978, and afterwards as Chemetals Corp. following purchase of the division on that date by Sedema, S.A., a Belgian producer of manganese compounds and a wholly owned subsidiary of the Brussells firm, Soc. Carbochimique S.A. Shipments of ferromanganese from U.S. furnaces totaled 330,000 tons in 1979, compared with 318,000 tons in 1978 and 338,000 tons in 1977.

The ferromanganese production reported in the various tables of this chapter is net production; that is, the quantity of ferromanganese produced for shipment outside the producing ferroalloy facility. It does not include the remelt material; that is, the fines, offgrade, or other ferromanganese output of the furnace that was fed back to the furnace or lost in the plant, and which is included in gross production data reported by the furnace operator.

Table 6.—Manganese ore used in producing ferromanganese, silicomanganese, and manganese metal in the United States in 1978-79, by source of ore

Source	1978		1979	
	Gross weight (short tons)	Mn content, natural (percent)	Gross weight (short tons)	Mn content, natural (percent)
Domestic[1]	90,660	45	125,130	47
Foreign:				
Africa	234,554	49	232,687	49
Australia	35,977	50	66,572	51
Brazil	268,351	49	311,938	51
Chile[1]	--	--	1,885	45
Cuba[1]	48,219	49	6,275	49
India	29,517	46	58,908	47
Mexico	36,190	41	40,707	39
U.S.S.R.[1]	17,105	49	8,333	48
Unidentified	70,698	--	58,269	--
Total	831,566	48	910,794	49

[1] Most, if not all, from U.S. Government excess stockpile disposals.

Silicomanganese.—Domestic production of silicomanganese increased to 165,000 short tons from 142,000 tons in 1978, and 120,000 tons in 1977. This is net production produced for shipment and does not include silicomanganese produced for use as an intermediate in the same plant for the production of medium- or low-carbon ferromanganese. Silicomanganese shipments from furnaces were 167,000 tons in 1979, compared with 153,000 tons in 1978, and 122,000 tons in 1977. Five companies used eight plants to produce silicomanganese for shipment in 1978: Airco Alloys Div., Airco Inc., Calvert City, Ky., and Theodore (Mobile), Ala.; Globe Metallurgical Div., Interlake Inc., Beverly, Ohio; Ohio Ferro-Alloys Corp., Philo, Ohio; Roane Electric Furnace Co. (Engelhard Minerals & Chemicals Corp.), Rockwood, Tenn.; and Union Carbide Corp., Alloy, W.Va., Marietta, Ohio, and Portland, Oreg. The same eight plants produced for shipment in 1979. End-use consumption of silicomanganese—that is, consumption outside the ferroalloy plants—was 17.6% that of ferromanganese in 1979, compared with 16.7% in both 1978 and 1977.

Spiegeleisen.—There was no domestic production of spiegeleisen.

Pig Iron.—A total of 596,000 short tons of manganese-bearing ores containing 5% or more manganese (natural) was consumed in 1978, 577,000 tons in 1979, in the production of pig iron (or its equivalent hot metal). Domestic sources supplied 368,000 tons in 1978, of which 322,000 tons was manganiferous iron ore containing 5% to 10% manganese and 46,000 tons was ferruginous manganese ore containing 10% to 35% manganese. In 1979 domestic sources supplied 347,000 tons, of which 310,000 tons was manganiferous iron ore and 37,000 tons was ferruginous manganese ore. Foreign sources supplied 228,000 tons in 1978, of which 9,000 tons was ferruginous manganese ore and 219,000 tons was manganese ore containing 35% or more manganese. In 1979 foreign sources supplied 230,000 tons, of which 1,000 tons was ferruginous manganese ore and 229,000 was manganese ore containing 35% or more manganese.

Battery and Miscellaneous Industries.—The ore reported in table 3 includes that consumed in making synthetic manganese dioxide by both electrolytic and chemical means, but it does not include consumption of synthetic dioxide. Although some synthetic dioxide is used for chemical purposes, most of it is used in the manufacture of dry-cell batteries, particularly for the manganese-alkaline type, for premium or heavy-duty Leclanché (manganese dioxide-ammonium chloride-zinc) cells, and for blending with natural ore in the ordinary Leclanché cells.

The domestic ore and much of the foreign ore used for chemical and miscellaneous purposes did not meet national stockpile specification P-81-R for chemical-grade ore.

About the beginning of 1978, Acme Battery Corp., Stamford, Conn., a producer of dry cells, was purchased by the French producer, Soc. Piles Wonder. A change in name was made to Acme Battery Division, Wonder Corporation of America.

PRICES

Manganese Ore.—All manganese ore prices are negotiated. In addition to manganese content, they are dependent on the chemical analysis otherwise, physical character, quantity, delivery terms, ocean freight rates, insurance, inclusion or exclusion of duties if applicable, buyer's needs, and availability of desired ores. Trade journal quotations reflect the paper's evaluation of the market. A representative contract price for both 1978 and 1979 delivery of metallurgical ore containing 48% manganese was $1.40 per long ton unit, c.i.f. U.S. ports, compared with $1.48 for 1977. Some 1979 contracts were for a quarter year delivery instead of a year, and apparently more spot sales were being made than had been the case. Prices as low as $1.36 in the first half of the year increased later due to rising ocean freight rates.

Manganese Alloys.—The published domestic producer price for standard high-carbon ferromanganese, having a minimum manganese content of 78%, increased $25.50 in May 1978 to $425 per long ton of alloy, f.o.b. shipping point, and to $440 in December. Three subsequent increases brought it to a dual price of $490-$530 for the last 2 months of 1979, but reportedly with some discounting. Prices for imported ferromanganese of the same manganese content (although not necessarily comparable in quality, delivery terms, or other respects) were reported to have increased gradually from a low of about $300, f.o.b. Pittsburgh or Chicago warehouses, for the first half of 1978 to a high of $450-$490 for the summer of 1979, and then dropping to close the year at $430-$440.

Manganese Metal.—Actual prices for standard and comparable grades of electrolytic manganese metal chips, packed in pallet boxes, continued through 1978 to be discounted from the list price, which remained at 58 cents per pound, f.o.b. producer plant, shipments of 30,000 pounds or more; the bulk price was 1 cent lower. In June 1979, Foote Mineral Co. stated that it was removing all discounts from manganese metal chips and selling at the list price. This price was increased to 62 cents, effective October 1 by Foote, November 15 by Kerr McGee, and December 1 by Union Carbide.

FOREIGN TRADE

Exports of ferromanganese were 25,344 short tons valued at $19,251,732 in 1979, compared with 9,433 tons at $4,768,594 in 1978 and 6,051 tons at $3,391,108 in 1977. Of the 1979 and 1978 totals (1978 in parentheses), Canada took 13,345 (3,197) tons; Mainland China, 4,251 tons; the Netherlands, 2,456 tons; the Federal Republic of Germany, 2,122 (1,242) tons; Mexico, 1,189 (1,015) tons; Ghana, 922 (342) tons; Sweden, 829 (367) tons; Colombia, 99 (86) tons; Venezuela, 73 (57) tons; Panama, 28 tons; United Kingdom, 17 tons; Chile, 6 (22) tons; Malaysia, 5 tons; Dominican Republic, 2 tons; Iran, (3,030) tons; Guatemala, (55) tons; the Netherlands Antilles, (19) tons; and Brazil, (1) ton. Exports classified as " manganese and manganese alloys, wrought .or unwrought, and waste and scrap" totaled 6,634 tons having a value of $7,463,116 in 1979; 6,138 tons and $5,165,124 in 1978; and 2,953 tons and $3,027,681 in 1977. This classification included electrolytic manganese metal and manganese-copper alloys, but it did not include ferromanganese or silicomanganese.

Beginning with January 1978 data, silicomanganese exports have become identifiable by being placed in a class by themselves. Exports of silicomanganese totaled 5,243 tons with a value of $2,627,474 in 1979, and 4,782 tons valued at $1,568,201 in 1978. Canada took the largest portion in both years, 4,989 and 1,711 tons, respectively. In 1979, the remainder went to Dominican Republic (196 tons), Mexico, Bolivia, and Brazil; in 1978, to the United Kingdom (1,120 tons), the Federal Republic of Germany (1,087 tons), Sweden, Brazil, Mexico, Republic of South Africa, Taiwan, Chile, and New Zealand. Exports of ore and concentrate containing more than 5% manganese amounted to 58,323 tons valued at $5,697,532 in 1979 and 200,128 tons at $13,122,883 in 1978. Of the totals, large quantities having relatively low average values went in 1979 to Mexico (23,317 tons) and Norway (17,228 tons); in 1978, to Canada and Norway (each 79,000 tons) and Mexico (16,000 tons). Much of the remainder is believed to have been imported manganese dioxide ore that may or may not have been subjected to grinding, blending, or otherwise classifying in the United States. In 1979, Canada received 12,000 tons with average values (for customs districts) ranging from $106 to $192 per short ton; in 1978, Singapore received 17,000 tons with an average value of $100. The new 1978 export schedule of The Bureau of The Census, Schedule B, beginning with January 1978 data, placed the lower limit for manganese content of ore concentrate at 5%.

The manganese ore imported in 1979 had an average manganese content of 49%, compared with 51% in 1978, and 49% in both 1977 and 1976. Gabon supplied 29% of the total in 1979 and more than 45% in 1978. The Republic of South Africa supplied 23%, Australia 22%, and Brazil 21% in 1979. In 1978, Brazil provided 19% of that year's total imports, and Australia 10%. A relatively small quantity of manganiferous ore (more than 10% but less than 35% manganese) was imported each year from Mexico: 400 tons averaging 32% manganese in 1979 and 1,100 tons averaging 30% manganese in 1978. The 1978 imports of manganese ore were the lowest they have been in 40 years; those for 1979 were even lower.

Ferromanganese imports increased to successive record highs with the Republic of South Africa supplying 44% of the total in each year and France 18% in 1979 and 22% in 1978. Silicomanganese imports for consumption totaled 94,671 short tons containing 62,608 tons of manganese in 1979; 94,644 tons containing 63,194 tons of manganese in 1978. Sources and gross weight tonnages for the 2 years were as follows (1973 in parentheses): Brazil, 28,871 (17,220); Norway 25,517 (24,691); Yugoslavia, 17,863 (19,235); Republic of South Africa, 8,818 (3,044); France, 7,219 (3,303); Spain, 2,849 (2,215); Mexico, 2,042 (9,029); Canada, 873 (1,495); Australia, 619 (2,206); Portugal, (11,839); and Japan (367). Imports for consumption classified as unwrought manganese metal, and metal waste and scrap, totaled 6,683 short tons in 1979, 9,113 tons in 1978, 6,841 tons in 1977. Sources for the 2 years were (1978 in parentheses): Republic of South Africa, 6,114 (7,809) tons; Japan, 220 (1,180) tons; Republic of Korea (South), 238 tons; Canada, 111 (107) tons; and Sweden, (17) tons. It is most probable that the metal from Canada and Sweden originated in the Republic of South Africa. However, of the imports from Canada, approximately 90 tons in 1979 and 65 tons in 1978 was too low in value to be metal. No spiegeleisen was imported in 1979. That imported in 1978 totaled 3,134 short tons, of which 3,076 tons came from France and 58 tons from Japan.

Beginning with January 1978 data, inorganic chemical imports classified as "manganese compounds, other" have been broken down into two subclasses: Manganese dioxide, and manganese compounds other than manganese dioxide, borate, or sulfate. The manganese dioxide imports for consumption totaled 9,862 short tons in 1979 and 6,830 short tons in 1978. Of these quantities, approximately 9,300 tons in 1979 and 6,400 tons in 1978 was apparently battery-grade synthetic dioxide: 4,095 and 4,052 tons, respectively, from Japan; 3,853 and 1,006 tons from Greece; 1,190 and 1,131 tons from Belgium; 119 tons and 198 tons from Ireland. Manganese sulfate imports were 144 tons in 1979 and 48 tons in 1978. Belgium supplied 119 tons in 1979, but only 1 ton in 1978; Japan, 23 and 45 tons, respectively; 1 ton each came from the Federal Republic of Germany and Mexico in 1979, and from the Federal Republic of Germany and Canada in 1978.

Tariffs.—The duty of 0.12 cent per pound of contained manganese on manganese ore from most nations remained suspended through June 30, 1979, at which time suspension lapsed and the duty became applicable. Effective January 1, 1980, manganese ore and manganiferous ore from most favored nations became free of duty. H.R. 5441, a Bill to Amend the Tariff Schedules of the United States with respect to the tariff treatment of certain articles, including provision for relief of duty paid during the lapsed period, passed the House December 3, 1979, and was awaiting Senate action at the end of the year. The statutory rate remained at 1 cent per pound of contained manganese, and continued to apply to ore from the U.S.S.R. and Mainland China. The respective rates of duty for metal and the principal manganese ferroalloys remained unchanged. Qualifying developing nations continued to receive the benefit of duty-free treatment under the Generalized System of Preferences (GSP) with respect to U.S. imports of ferromanganese and silicomanganese.

Table 7.—U.S. imports[1] of manganese ore (35% or more Mn), by country

Country	1978			1979		
	Gross weight (short tons)	Mn content (short tons)	Value (thousands)	Gross weight (short tons)	Mn content (short tons)	Value (thousands)
Australia	54,421	32,598	$3,063	109,505	55,316	$5,413
Brazil	102,870	52,096	5,060	104,632	51,660	5,471
Congo[2]	[3]18,945	[3]9,472	1,299	44,920	22,460	2,563
Gabon[4]	249,683	126,962	16,560	98,913	49,222	6,721
Mexico	46,053	18,355	2,105	4,590	2,059	245
Morocco	26,967	14,522	1,963	21,790	[5]10,719	2,121
South Africa, Republic of	[6]22,400	[6]10,976	1,288	115,433	52,117	4,951
Zaire	26,462	13,231	1,643	--	--	--
Total[7]	547,820	278,212	32,981	499,782	243,553	27,485

[1] Quantities for general imports and imports for consumption were identical.

[2] Believed to have originated in Gabon.

[3] Bureau of Mines interpretation of reported data. Being questioned.

[4] In addition, in 1978 the 18,945 tons credited to Congo, and in 1979 the 44,920 tons so credited, were believed to have originated in Gabon.

[5] Bureau of Mines conversion of reported data (from apparent MnO_2 content to Mn content).

[6] Reported gross weight assumed to be correct. Content estimated by Bureau of Mines at 49% Mn. Being questioned.

[7] Data may not add to totals shown because of independent rounding.

Table 8.—U.S. imports for consumption of ferromanganese, by country

Country	1978			1979		
	Gross weight (short tons)	Mn content (short tons)	Value (thousands)	Gross weight (short tons)	Mn content (short tons)	Value (thousands)
Australia	26,366	20,485	$5,550	27,658	21,595	$6,104
Belgium-Luxembourg	--	--	--	6,212	4,721	2,254
Brazil	25,931	20,016	6,232	29,573	22,498	9,590
Canada	25,877	20,312	6,741	11,133	8,073	2,029
France	146,633	113,870	40,826	150,623	117,225	50,553
Germany, Federal Republic of	--	--	--	11,029	8,706	[1]3,045
India	8,337	6,248	1,567	16,900	12,858	5,462
Italy	2,213	1,815	1,130	--	--	--
Japan	454	376	234	28,532	22,785	13,222
Mexico	36,216	28,416	9,060	39,088	30,535	12,298
Norway	37,624	29,635	10,862	61,821	48,250	18,673
Portugal	32,445	25,642	7,151	37,395	28,997	11,717
South Africa, Republic of	302,229	236,063	77,513	363,744	282,558	106,213
Spain	19,651	15,568	6,725	12,094	10,156	6,406
Taiwan	660	483	200	--	--	--
United Kingdom	--	--	--	5,367	4,079	1,160
Yugoslavia	15,763	12,256	4,064	19,345	14,701	6,169
Total[2]	680,399	531,196	177,845	821,213	638,734	[1]254,843

[1] Bureau of Mines figure (reported figures were 5,045 and 256,843.)

[2] Data may not add to totals shown because of independent rounding.

WORLD REVIEW

Representatives of six developing countries, Brazil, Gabon, Mexico, Morocco, Upper Volta, and Zaire, all manganese ore producers, or potential ore producers, met September 19-22, 1978, in Libreville, Gabon, to discuss marketing and pricing problems, including erosion of the real (constant) price that has occurred since 1957; also, the potential market impact of manganese recovery from sea-floor nodules. An additional objective was development of a common position for future meetings with consumers. Representatives of the United Nations Conference on Trade and Development (UNCTAD) and the United Nations Development Program (UNDP) also participated. Before adjourning, a communique was issued proposing formation of a "manganese forum," to be associated with UNCTAD and consisting of both producing and consuming countries. This would establish an organization for continued study of the problems pending completion of an international agreement on manganese.

Three international consortia, each having U.S. company participation, in 1978 tested ships and equipment for recovering manganese nodules from the Pacific ocean floor at depths of 15,000 feet or more. Ocean Mining Associates (United States Steel, Union Miniere, and Sun Oil) reported that its test mining ship, Deepsea Miner II, successfully raised manganese nodules from the ocean floor at a depth of 3 miles at the design capacity of 50 tons per hour. The test ship, a 20,000-ton converted ore carrier, unloaded its cargo at San Diego in mid-December after returning from the mining site some 1,200 miles southwest of that port. The nodules were to be used as a bulk sample for process development tests. Announcement of these developments was tempered by a caution that many engineering problems remain to be solved before commercial mining can be achieved. In the spring and summer of the year, Ocean Management Inc., the consortium in which International Nickel Co. (INCO) and SEDCO exercise their interest, recovered 700 tons or more of nodules from a depth of 17,000 feet using both hydraulic and pneumatic lift systems. It was INCO's opinion that technical feasibility was established, but that it would be at least the mid or late 1980's before production could be economic. Ocean Minerals Co., the group headed by Lockheed Corp., brought up several thousand pounds of nodules from a depth of 18,000 feet, planned further tests, and announced that a $4,000,000 pilot plant would be built on Oahu, Hawaii, to study and test metallurgical processing of the nodules. Construction had not started by the end of 1979.

Uncertainties concerning proposed Law of the Sea and/or unilateral deepsea mining legislation, as well as the deteriorating general market situation for the metals of interest in the nodules, served to curtail the activities of most consortia following completion of sea tests. The tests continued to be monitored by the National Oceanic and Atmospheric Administration (NOAA) through its Deep Ocean Mining Environmental Study (DOMES) project. Ocean Mining Associates continued to be the only group avowedly interested in first-generation manganese recovery, although there were indications that others were giving it more consideration than they had previously.

Argentina.—Production of rhodochrosite, mined as a semiprecious stone rather than an ore, was 42 metric tons in 1978.

Australia.—Of the 1,617,000 wet metric tons of manganese ore shipped from Groote Eylandt in 1979, 1,157,000 tons were exported with 700,000 tons going to Asia, 337,000 tons to Europe, and 120,000 tons to the United States. In 1978 total shipments from the mine were 1,300,000 tons, of which 910,000 tons were exported.[2] The manganese ore produced in Australia in 1978 had an average manganese content of 48.7%.

Bolivia.—In 1977, manganese ore mined by small producers, and amounting to 2,576 metric tons, was shipped to Argentina. The average grade was 54% manganese, 1.3% iron, and 0.75% arsenic. It was required that the ore be marketed through SIDERSA.

Brazil.—Industria e Comércio de Minerios S.A. (ICOMI) shipped 1,189,800 metric tons of manganese ore products, including pellets, in 1979 from its Serra do Navio operations, Amapa Territory. Of this quantity, 804,900 tons went to Europe, 183,500 tons to Asia, 174,100 tons to North America, and 27,300 tons to South America.[3] Shipments by the company in 1978 totaled 783,300 metric tons loaded out of the Amazon River port of Santana in 52 cargo vessels. Of this total, 502,100 tons was exported to Europe, 129,600 tons to North America, 77,100 tons to Japan, and 20,900 tons to South America. Shipments to domestic consumers in Brazil were 53,600 tons.[4] SIBRA, the Bahia ferromanganese producer, was one of the principal domestic customers in these years. ICOMI was reported to be planning to spend approximately $3 million for prospecting and exploration in 1979, particularly in the Serra do Navio mine area and in Mato Grosso. The company's pellet production in 1978 was 180,700 metric tons.

Of the manganese ore produced in Brazil in 1977, 709,000 tons was ICOMI washed ore and concentrate, 111,000 tons was ICOMI pellets, and 254,000 tons averaging 35.4% manganese was produced for domestic consumption from the Morro da Mina mine in the Lafaiete area of Minas Gerais. In addition to scattered production in Bahia, Goias and elsewhere, three companies produced ore in the Corumba district of Mato Grosso, near the Bolivian border: Urucum Mineração S.A., Urucum mine, 120,000 tons averaging 46% manganese and 11% iron; Mineração Mato Grosso (controlled by the Sao Paulo ferroalloy producer, Cia. Paulista de Ferro-Ligas), Santana mine, 38,000 tons

Table 9.—Manganese ore: World production, by country

(Short tons)

Country[1]	Percent Mn[e]	1976	1977	1978[p]	1979[e]
North America: Mexico[2]	35+	499,579	536,408	576,691	600,000
South America:					
Argentina	25-30	58,517	90,814	108,478	100,000
Bolivia[2 3]	28-54	13,521	9,464	1,364	[4]409
Brazil[5]	38-50	1,869,728	1,670,741	[e]1,800,000	1,875,000
Chile	36-40	26,058	19,843	25,621	25,000
Peru	26	[4]676	--	--	--
Europe:					
Bulgaria	30-	44,100	44,100	[e]44,100	44,100
Greece	48-50	9,075	8,631	7,727	[4]6,338
Hungary[6]	30-33	138,000	132,000	126,000	115,000
Italy	22+	4,917	10,267	10,738	10,000
U.S.S.R.[7]	35	9,520,000	9,470,000	9,984,000	[e]10,500,000
Yugoslavia	30+	20,944	27,282	29,800	30,000
Africa:					
Egypt	28+	4,691	4,225	191	--
Gabon	50-53	2,443,556	2,009,857	1,831,157	2,000,000
Ghana	30-50	343,780	321,417	347,863	300,000
Morocco	53-50	129,305	125,164	139,111	150,000
South Africa, Republic of	30-48+	6,009,835	5,564,411	4,758,721	[4]5,712,549
Sudan	48	505	504	496	500
Zaire	30-57	200,824	42,216	--	--
Asia:					
China, Mainland[e 8]	20+	1,100,000	1,100,000	1,400,000	1,650,000
India[9]	10-54	[r]2,022,604	2,055,865	1,727,320	1,800,000
Indonesia	47-56	10,839	6,593	6,492	5,000
Iran[10]	33+	44,100	44,100	33,100	25,000
Japan	26-28	156,244	138,931	118,484	100,000
Korea, Republic of (South)	23-40	1,524	732	823	500
Pakistan	35-	71	58	317	400
Philippines	40-45	11,658	22,706	4,311	4,000
Thailand	46-50	55,364	84,767	79,513	[4]27,961
Turkey	35-46	[r]18,696	21,275	22,046	33,000
Oceania:					
Australia	37-53	2,374,560	1,531,113	1,421,978	[4]1,896,000
New Hebrides[11]	40-44	38,664	27,246	23,712	[4]11,896
Total	NA	[r]27,171,945	25,153,730	24,622,149	26,962,952

[e]Estimate. [p]Preliminary. [r]Revised. NA Not available.

[1] In addition to the countries listed, Colombia, Cuba, and the Territory of South-West Africa (Namibia) may have produced manganese ore and/or manganiferous ore, but available information is inadequate to make reliable estimates of output levels. Low-grade ore not included in this table has been reported as follows in short tons: Czechoslovakia (about 17% Mn) 1976-1,211, 1977-1,003, 1978-(estimate) 1,000, 1979-(estimate) 1,000; Malaysia (grade unspecified but apparently a manganiferous ferruginous ore) 1976-103,741, 1977-50,040, 1978-47,092, 1979-(estimate) 50,000; Romania (about 22% Mn) 1976-(revised estimate) 90,000, 1977-(revised estimate) 90,000, 1978-(estimate) 90,000, 1979-(estimate) 90,000; the Republic of South Africa (15-30% Mn, in addition to material listed in table) 1976-56,178, 1977-266,930, 1978-105,490 1979-nil.

[2] Estimated on the basis of reported contained manganese.

[3] Exports.

[4] Reported figure.

[5] Figures are the sum of (1) sales of direct shipping manganese ore, and (2) production of beneficiated ore, both as reported in the 1977 and 1978 editions of Annuario Mineral Brasileiro.

[6] Concentrate. Crude ore tonnages (18%-26% Mn) as previously reported were 1976-181,963, 1977-177,061, 1978-172,160, 1979-(estimate) 165,000.

[7] Source: 1976-78, The National Economy of the U.S.S.R., Central Statistical Administration, Moscow; 1979, Pravda, Moscow. Grade represents the annual averages obtained from reported metal contents of the gross weights shown in the table for 1976-78.

[8] Includes manganiferous ore.

[9] Much of India's production grades below 35% Mn; recent details on output by grade are not available, but in 1976, 65% of total exports of 787,533 short tons were below 35% Mn.

[10] Reported as if data are for calendar years, but may actually represent output for Iranian calendar years beginning March 21 of the year stated.

[11] Japanese imports.

at 45% manganese and 5% iron; and Sociedade Brasileira de Imoveis Ltda. (SOBRAIMOVE), (Chamma group) Jacadiga mine, 33,800 tons at 48% manganese and 9% iron. Production from the district was exported by barge to Argentina or trucked/railed to the Sao Paulo domestic market, and in 1978 also shipped to the new Corumba ferromanganese plant of Cia. Paulista de Ferro-Ligas. Early in 1978, Urucum Mineração reportedly contracted to ship 100,000 tons of ore to Japan beginning in 1979. A fourth company, Mineração Corumbaense Reunida Ltda., organized with Brazilian and Argentinian capital and headquartered in Corumba, was developing manganese and iron deposits in 1979 in the Santa Cruz range of Mato Grosso. Plans were for an ultimate annual production rate of 500,000 tons of manganese ore, averaging 46% manganese, and 3 million tons of iron ore; the latter to be exported through the company's Porto Esperanca port installation, and the manganese ore placed domestically.

Of total Brazilian manganese ore exports of 603,000 tons (including ICOMI pellets) in 1977, ICOMI accounted for 505,300 tons, Urucum Mineração 74,000 tons, and SOBRAIMOVE 23,700 tons. Imports for the year included 61,600 tons of manganese ore and 253 tons of metal. Apparent Brazilian consumption of manganese was the equivalent of 500,000 tons of ore.

In March 1978, United States Steel Corp. sold the Morra da Mina mine of its Brazilian subsidiary Cia. Meridional de Mineração Ltda., to a subsidiary of Cia. Paulista de Ferro-Ligas. United States Steel had owned the mine since 1920 and for many years it was a major source of oxide ore. In recent years its production was barred from export and Cia. Paulista has been the largest consumer. Of the 254,000 tons of ore produced in 1977, 187,000 tons was the calcined product of carbonate ore which makes up the mine's remaining reserves.

Canada.—The Beauharnois, Quebec, ferroalloy plant of Union Carbide Canada, Ltd., was struck November 25, 1978, but the Tanabe electric-arc closed-top furnace continued production of standard high-carbon ferromanganese by supervisory personnel until January 9, 1979, when an explosion and fire that killed five of the operators stopped all production. Cause of the explosion was the collapse of a hang-up of the charge in the furnace, a problem with ferromanganese production in earlier closed electric-arc furnaces that was supposedly eliminated by the safety features of this furnace. It was the largest furnace of its type in the world, rated as capable of producing 100,000 tons per year. After 9 months, the strike was settled but ferromanganese production was not resumed.

Canal Zone.—A total of 493,000 metric tons of manganese ore and concentrate passed through the Panama Canal in 1977, with 257,000 tons going from the Atlantic to the Pacific, and 236,000 tons in the opposite direction.

Chile.—Manganese ore production had an average grade of 34.5% manganese in 1979, 35.7% in 1978, and 39.0% in 1977.

China, Mainland.—Experimental work by the Zunyi ferroalloy plant, Guizhov Province, and the Peking Iron and Steel Research Institute, had reportedly been successful in producing low- and medium-carbon ferromanganese from high-carbon ferromanganese in top-blown oxygen converters. This procedure has been used in the Federal Republic of Germany and in Finland.[5]

Egypt.—Kaiser Engineers and Constructors Inc., a unit of Raymond International Inc., was awarded a contract by Sinai Manganese Co. to investigate, in association with the Arab Consulting Bureau, the feasibility of mining resumption at Om Bogma and completion of the 10,000 ton-per-year ferromanganese plant at Abu Zeneima which was under construction and nearly completed in 1967 when the Sinai was lost to Israel. The Agency for International Development (AID), U.S. Department of State, was to provide funds for the study and/or the developments that might result from it. The small quantity of manganese ore produced in Egypt in 1978 averaged between 28% and 35% manganese.

France.—Western Europe's largest blast furnace producer of standard high-carbon ferromanganese, Societe des Acieries de Paris et d'Outreau, in which United States Steel Corp. maintained a 27% interest, was placed in receivership in December 1978. It was agreed that operations would be taken over by the Gabonese manganese ore producer, Cie. Minière de l'Ogooué, or its Paris-based subsidiary, Comireg. Effective January 1, 1979, operations were to be managed by a new company, Societe du Ferromanganese Paris-Outreau, with actual ownership being effected after 2 years. In December 1978, the company's three blast furnaces were operating normally. Plans were to halve the number of employees to 650, and with the help of the Government to invest $7 million in modernization of the plant.[6] Much of the company's output is exported to United States Steel Corp. and other U.S. consumers. The company, along with other European Economic Community ferromanganese producers, has been adversely affected by low-priced exports from developing country, or "third country," producers.

Gabon.—Of total 1979 manganese ore shipments of 2,308,000 metric tons by Cie. Miniére de l'Ogooué (COMILOG), 2,206,500 tons were metallurgical ore and 101,500 tons were battery-grade ore.[7] The 1978 total of 1,694,400 tons was divided into 1,603,000 tons metallurgical ore and 91,400 tons battery ore. The ore was loaded out of the Congo port of Pointe Noire in 99 vessel cargoes. Comilog shipments in 1977 totaled 1,859,000 tons,[8] but the Gabonese "Statistiques du Commerce Exterieur" reported total Gabon exports for that year as 2,162,000 tons, which included 620,000 tons to Canada, 357,000 tons to France, 257,000 tons to Japan, 243,000 tons to the United States, 148,000 tons to Spain, and 131,000 tons to Sweden. The Comilog figures apparently were shipments from the port in the Congo; the government figures, shipments (exports) out of Gabon. Manganese ore provided 7.6% of Gabon's export earnings in 1978. Production of battery- and chemical-grade ore in 1979 was 111,600 metric tons averaging 82% manganese dioxide, valued at $145 per metric ton; in 1978, 93,400 tons containing from 83% to 85% manganese dioxide valued at $135 per ton. The metallurgical ore produced in both years averaged 51% manganese, valued at $49.50 per metric ton in 1979 and $51 in 1978. Problems with the Congo Railroad and at the mine, which continued to be the country's only producer, had an adverse effect on 1978 production and shipments.

Construction of the first section of the Transgabon Railroad, from Libreville-Owendo to Ndjole, was essentially complete at the end of 1978 and some irregular use begun. Regularly scheduled use was not expected before April 1979, and completion of the line to Franceville was scheduled for 1985.

Germany, Federal Republic of.—In June 1979 the Government approved the establishment of a 1-year strategic stockpile for manganese and certain other mineral commodities. The acquisitions will be made over a 5-year period by private companies with Government assistance.

Ghana.—Ghana National Manganese Corp., the country's only manganese ore producer, exported 263,000 long tons, bill of lading weight, of manganese ore in 1979 from the Nsuta mine through the port of Takoradi, located 39 miles from the mine. The ore was loaded out in 33 vessel cargoes to eight countries: United Kingdom, Japan, Ireland, Belgium, Spain, Norway, the Netherlands, and Portugal.[9] In 1978, 320,000 tons was shipped in 44 vessel cargoes to nine countries: United Kingdom, Japan, Belgium, Spain, Ireland, German Democratic Republic (East Germany), Norway, the Netherlands, and Portugal. Shipments in 1977 were 342,000 tons.[10] With the oxide ores approaching exhaustion and the market for the underlying carbonate ore limited, consideration was being given to the building of a plant to convert the carbonate ore to oxide nodules.

Greece.—The concentrates produced, reported in table 9, in 1979, 1978, and 1977 had a manganese content of 48% to 50%. The crude ore output contained from 20% to 35% manganese. In December 1978, Sunlight S.A., a member of the Scalistiri Group, began producing dry-cell batteries at Xanthi using battery-grade ore from the Group's Drama mines and synthetic (electrolytic) manganese dioxide produced at Thessaloniki by Tekkosha Hellas S.A. Know-how and equipment for this project were provided by Varta Baterrie A.G., Federal Republic of Germany.

India.—Manganese-bearing ore shipments from the port of Mormugao, Goa, in 1979 consisted of 11,000 metric tons of manganese ore and 398,000 tons of ferruginous manganese ore. In 1978, only ferruginous manganese ore in the amount of 240,000 tons was shipped.[11] The Indian manganese ore produced in 1978 came from 327 mines, and approximately half of the production was from 313 small mines producing less than 35,000 tons per year. Approximately 90% of the total output was from the States of Orissa, Karnataka, Madhya Pradesh, and Maharashtra. Manganese Ore India Ltd. (MOIL), the public sector company, produced more than 75% of all high-grade ore and more than one-fourth of the country's total production in 1978 and in 1977. About the end of 1978, MOIL planned to build an 80,000- to 100,000-metric-ton-per-year agglomeration plant at the company's Balaghat mine in Madhya Pradesh, the sinter or pellet product of which would be fed to a proposed 60,000-ton ferromanganese plant to be built at the mine. Feed to the agglomeration plant would be manganese ore fines containing 44% manganese to be provided by one or two beneficiation plants to be built also. In addition, bids were invited from several international firms for a technical and economic report on optimizing the company's manganese production and for a detailed report on one of its underground mines.

Power shortages resulting from failure of the monsoon and ensuing drought, together with shortages of diesel fuel, adversely affected India's ferromanganese industry in 1979 to the extent that ferromanganese exports were banned.[12]

Italy.—The privately owned Genoa firm, Societa SILMA, picked up the manganese ore concessions dropped by ITALSIDER and production of ore was resumed. The ore produced in 1978 averaged 22% manganese.

Japan.—Production of electrolytic manganese metal in 1978 was 6,463 metric tons, and that of synthetic manganese dioxide was 31,131 tons. The manganese ore produced in that year had an average manganese content of 28%. No battery- or chemical-grade natural ore was produced.

Korea, Republic of (South).—The small quantities of manganese ore produced in 1979 and 1977 had an average manganese content of 40%. In 1978 the ore produced graded between 23% and 35% manganese.

Mexico.—Shipments of manganese nodules in 1978 by Cia. Minera Autlán S.A. de C.V. from its Molango operations in the State of Hidalgo totaled 387,000 metric tons, averaging 39% manganese. Of the total, 216,400 tons was for domestic consumption and the remainder exported. In 1977, the company's shipments totaled 437,000 tons.[13] The company was reported to be building a third manganese ferroalloy furnace at its Tamos (Tampico) plant, which will increase ferromanganese productive capacity by at least 60,000 tons when it comes onstream about 1980. Approximately half of the plant's production is sold domestically, and most of the exported remainder goes to six U.S. steel mills. Plans also called for an increase in nodule production of at least 50% within 2 or 3 years.[14] The Federal Republic of Germany firm, Metallgesellschaft, joined with Cia. Minera Autlán in establishing a new metals marketing firm, Autmet.[15] In another venture, Japan's Matsushita Electric Industrial Co. reportedly was to join with Cia. Minera Autlán to form a company, owned 51% by Autlan and 49% by Matsushita, to produce dry-cell batteries in Mexico City. Initial production was planned for four million dry cells per month starting in 1981.

Morocco.—Of the manganese ore produced in 1979, 522 metric tons was metallurgical grade, and the remainder was chemical-grade ore averaging 84% manganese dioxide. All the ore produced in 1978 was chemical grade averaging 84% manganese dioxide. Exports of ore were 138,000 tons and 131,000 tons in 1978 and 1977, respectively.

New Hebrides.—The Australian firm, Southland Mining Ltd., granted an option for $50,000 to a New Caledonia company for the purchase of its manganese ore mining subsidiary, Le Manganese de Vaté, at a price of $2.5 million.[16] The ore produced and shipped in 1978 averaged 40% to 42% manganese. Shipments in that year were 20,700 dry metric tons before operations ceased in November.

Philippines.—Reported manganese ore production for 1978 was for unwashed ore containing 44% to 45% manganese.

Portugal.—Manganiferous iron ore produced in 1978 amounted to 34,760 metric tons averaging 36.7% iron and 7.6% manganese. Revised analyses for the 1977 production were 38.9% iron and 7.9% manganese. The only mine in production was the Cercal mine in the Alentejo.

Romania.—Two 33-megavolt-ampere ferromanganese furnaces were part of a new ferroalloy complex being brought onstream in 1979 at Tulcea.

South Africa, Republic of.—The Associated Manganese Mines of South Africa Ltd. shipped from its mines in Cape Province 1,741,000 metric tons of manganese ore and 1,253,000 tons of iron ore in 1979;[17] 1,758,000 tons of manganese ore and 563,000 tons of iron ore in 1978; 1,638,000 tons and 555,000 tons, respectively, in 1977.[18] Experimenting at its Kookfontein ferromanganese plant, SAMANCOR's subsidiary, Metalloys Ltd., was importing 20,000 tons of Brazilian manganese pellets to blend with ore from SAMANCOR's Wessels mine which has a high iron content of 15% with a manganese content of 46% to 48%. The results were to be compared with use of ore from SAMANCOR's Mamatwan mine which typically analyzes 6% to 7% iron and 38% to 40% manganese.[19] The first shipment of manganese ore from Anglo American Corporation of South Africa's Middelplaats mine left Port Elizabeth June 20, 1979. The shipment consisted of 14,360 tons destined for Western Europe. The entire 1979 expected production, estimated at 200,000 tons, was reported to have been sold.

Production of the various grades of ore in 1979, 1978, and 1977 follow, in metric tons (1978 and 1977 in parentheses, in that order): Metallurgical ore—30% to 40% manganese, 2,897,000 (2,357,000 and 2,839,000); 40% to 45%, 763,000 (430,000 and 577,000); 45% to 48%, 998,000 (1,131,000 and 1,198,000); over 48%, 296,000 (262,000 and 263,000); chemical ore—less than 35% manganese dioxide, 76,000 (19,000 and zero); 35% to 65%, 153,000 (118,000 and 171,000); 65% to 75% 200 (zero and 156) tons. No ferruginous manganese ore containing 15% to 30% manganese and 20% to 35% iron was produced in 1979. Production amounted to 96,000 tons in 1978 compared with 242,000 tons in 1977. Local sales and exports in 1977, in that order, were as follows: Metallurgical ore— 30% to 40%, 855,000 and 1,974,000; 40% to 45%, 23,000 and 15,000; 45% to 48%, 612,000 and 891,000;

over 48%, 97,000 and 168,000; chemical ore—35% to 65%, 151,000 and 8,100; 65% to 75%, 1,300 and 107; and ferruginous manganese ore, zero and 273,000 tons. Imports in 1977 totaled 4,900 tons of manganese ore; apparent consumption was 1,745,000 tons.

Thailand.—Production of battery-grade manganese ore was 6,600 metric tons in 1978 and 4,800 tons in 1977. Chemical ore production was 78 tons and 63 tons in 1978 and 1977, respectively. Exports of metallurgical ore totaled 47,000 tons in 1978 and 69,000 tons in 1977, mostly to Taiwan and Japan. Battery-grade ore exports were 550 tons in 1978 and 745 tons in 1977. There were no exports of chemical ore.

Turkey.—The manganese ore produced in 1978 was estimated to have a manganese content between 35% and 46%.

U.S.S.R. —By early 1979, U.S.S.R. exports of manganese ore to Japan were reported to have been virtually discontinued.[80] It appeared that increased domestic demand in the U.S.S.R., coupled with less ready availability of good ore from domestic deposits, was eliminating the U.S.S.R. as a factor in world trade apart from its exports to associated Eastern bloc countries. It has been suggested that the U.S.S.R. conceivably could before long become an importer of the better western ores.

Upper Volta.—In November 1977, Union Carbide Corp. dropped its interest in the multinational consortium that had been formed earlier to develop the Tamboa manganese deposit.

Yugoslavia.—Doubling the production of manganese concentrate at the Bosanka Krupa mines in Bosnia-Hercegovina to 60,000 tons per year was being achieved by expansion of the flotation plant.[81]

Zaire.—The Benguela Railway, which links the Kisenge manganese deposits of Shaba Province with the Angolan port of Lobito, was closed since August 1975 until at least April 1979 when a test trainload of manganese ore was reported both to have arrived safely at Lobito, and not to have arrived safely, depending on source of the information. The only thing certain seemed to be that some manganese ore reached Lobito by the end of 1979, but the line continued to be subject to guerrilla attack in Angola. The European Economic Community (EEC), the Organization of Petroleum Exporting Countries (OPEC), and several western countries agreed to lend funds for rehabilitation of the line reported to be in a serious state of disrepair.

TECHNOLOGY

After study of small samples of manganese nodules from both the Atlantic and the Pacific Ocean floors, the Bureau of Mines concluded that the deepsea nodules have sufficient potential as oxidation catalysts for control of air pollution to warrant more extensive investigation when commercial production of the nodules becomes an actuality.[82]

The Bureau extended its previous development of cast manganese-copper high-damping manganese-copper alloys to powder metallurgy (P/M) consolidation of alloys containing 55% to 75% manganese by weight. The work demonstrated that high-damping manganese-copper alloys can be consolidated by P/M techniques. However, the aged alloys produced had significantly lower tensile strength, elongation, and hardness than did similarly treated wrought and cast alloys of the same compositions. Extension of the sintering periods or other treatment to refine structures and increase density can be expected to reduce the differences. Additions of 1% to 3% tin or zinc were investigated. Successful powder metallurgy should offer substantial savings in materials and processing costs, and might be quieter in service than wrought or cast parts.[83]

The role of manganese as an alloying element for aluminum was reviewed "from both a scientific and practical point of view." New metallurgical techniques, such as "splat cooling," were under development at laboratory scale and appeared to offer possibilities for future commercial production of alloys with relatively high manganese contents. The principal use for manganese additions to aluminum is to improve resistance to corrosion. Manganese additions also increase strength and hardness, but reduce ductility. The monograph has three major parts: (1) structure and properties of the various aluminum-manganese alloying systems, (2) commercial alloys, and (3) fabrication.[84]

Kennecott Copper Corp. developed a new closed-cycle hydrometallurgical process, the KCC Cuprion Process, for recovering nickel, copper, cobalt, and molybdenum from seabed manganese nodules. The process, tested in a pilot plant treating 350 kilograms per day, was demonstrated to be commercially viable. The manganese contained in the nodules goes to the tailings as carbonate, and expectations were that it could be recovered later if market conditions were favorable.[25]

With increasing costs of the various alloying agents used in steel and other metals, and less ready availability of some, metallurgists in both the United States and abroad were reportedly looking to greater and better use of the cheaper and more readily available manganese in order to achieve the same alloy properties.

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Mercury

By Harold J. Drake[1]

Mercury production was reported from three mines, two in Nevada and one in California. Increased production in 1979 was due primarily to higher prices, which prevailed throughout the year. Secondary production also increased in 1979. Part of the total supply was from sales by the General Services Administration (GSA).

An overall decline in consumption was led by reduced demand for mercury use in catalysts, paints, dental equipment, and for general laboratory purposes. Increased use was reported by chlorine and caustic soda manufacturers. Producer, consumer, and dealer stocks fell sharply. The average monthly price rose through the first half of 1979 but then fell off through August before beginning a rise that continued through the end of the year. The average annual flask price in New York was $281.10.[2]

Imports for consumption decreased by 39% from the 1978 level, to 26,448 flasks; but imports nonetheless accounted for over 50% of U.S. mercury consumption in 1979. Japan, Italy, Spain, Canada, and Mainland China were the principal sources of imported mercury.

Producers in Italy, Spain, and the U.S.S.R. reportedly continued to restrict sales of mercury during most of 1979; and Italian, Yugoslavian, and Mexican producers continued to sharply curtail or completely shut down mercury mining operations. Canadian mining operations, suspended in 1975 because of low prices, did not reopen in 1979. An international association of mercury producers that was formed in 1975, reportedly met intermittently during 1979. The group continued to advocate price stabilization by curtailing production, withholding supplies from the market, restricting sales to dealers, and closely controlling sales agents.

Legislation and Government Programs.—GSA offered 1,000 flasks of mercury for sale each month during 1979 and sold 11,300 flasks. GSA obtained the mercury from other Government agencies. At yearend, the strategic stockpile contained 194,290 flasks, which was 140,286 flasks more than the 54,004 flask goal.

In order to obtain public comment, the Environmental Protection Agency (EPA) published in 1978 its proposed plan for implementing the Toxic Substances Control Act which was passed in 1976.[3] Although mercury was not included in the initial list of toxic substances, the metal was being evaluated by EPA to determine if there is a need for its regulation. Mercury lost in past years during chlorine manufacturing continues to find its way into rivers adjacent to former production plant sites.[4] The mercury content found in fish in these waters greatly exceeded guidelines that have been established for edible foods by the U.S. Food and Drug Administration. These guidelines resulted in the bans on fishing for food purposes in these areas several years ago.

Information on the production, geology, and ore reserves of mercury deposits in Oregon was developed for inclusion in the Bureau of Mines Minerals Availability System.[5] A report on the mercury deposits of Turkey was published.[6] The study details the mineralogy, geology, size, and grade of deposits and includes a brief history of Turkey's productive mines.

Table 1.—Salient mercury statistics

	1975	1976	1977	1978	1979
United States:					
Producing mines	13	7	5	2	3
Production ..... flasks	7,366	23,133	28,244	24,163	29,519
Value ..... thousands	$1,165	$2,806	$3,833	$3,705	$8,299
Exports ..... flasks	339	501	852	NA	NA
Reexports ..... do	155	12	101	NA	NA
Imports:					
For consumption ..... do	43,865	44,415	28,750	43,148	26,448
General ..... do	44,472	43,964	28,750	43,964	28,819
Stocks, Dec. 31 ..... do	25,549	31,734	34,178	38,749	27,582
Consumption ..... do	50,838	64,870	61,259	48,766	45,442
Price: New York, average per flask	$158.12	$121.35	$135.71	$153.32	$281.10
World:					
Production ..... flasks	252,329	r248,274	r199,539	183,579	192,845
Price: London, average per flask	$130.11	$91.97	$140.70	$131.57	$291.73

NA Not available. rRevised.

DOMESTIC PRODUCTION

Three mines reported production; the Carlin gold mine and the McDermitt mercury mine, both in Nevada, and the Knoxville mine in California. The increased output of primary mercury was accounted for mainly by the McDermitt mine. Most small mercury mines in the United States remained closed despite the higher prices in 1979. The average grade of all ore processed in 1979, including ore processed at concentrators, increased from 7.2 pounds of mercury per ton in 1978 to 7.5 pounds per ton in 1979.

Production of secondary mercury amounted to 4,287 flasks, which was 20% above that of 1978. Most of the increase in secondary production was attributed to higher mercury prices, which made it more economical to extract mercury metal from lower-grade scrap material. Major sources of secondary mercury were industrial and control instruments, batteries, sludges, and dental amalgams.

Table 2.—Mercury produced in the United States

Year and State	Producing mines	Flasks	Value[1] (thousands)
1978			
California and Nevada	2	24,163	$3,705
1979			
California and Nevada	3	29,519	8,299

[1] Value calculated at average New York price.

Table 3.—Mercury ore treated and mercury produced in the United States[1]

Year	Ore treated (short tons)	Mercury produced	
		Flasks	Pounds per ton of ore
1975	76,772	6,905	6.8
1976	185,103	23,042	9.5
1977	216,577	28,244	9.9
1978	256,197	24,144	7.2
1979	241,684	29,499	7.5

[1] Excludes mercury produced from old surface ores, dumps, and placers, and as a byproduct.

Table 4.—Production of secondary mercury in the United States

(Flasks)

Year	Industrial production	GSA releases	Total
1975	7,538	500	8,038
1976	2,843	520	3,363
1977	5,566	1,000	6,566
1978	3,560	5,702	9,262
1979	4,287	11,300	15,587

CONSUMPTION AND USES

In 1978, the Bureau of Mines used the Standard Industrial Classification code for reporting consumption data and developed detailed data not previously available on electrical and instrument uses.

Of the mercury consumed in 1979, 82% was primary mercury, 15% was redistilled mercury, and the remainder was secondary mercury. Primary mercury was used throughout the whole range of mercury applications, and redistilled mercury was used primarily in electrical apparatus, industrial and control instruments, and dental preparations. Secondary mercury was used mainly in industrial and control instruments, chemicals, electrical apparatus, and catalysts.

Table 5.—Mercury consumed in the United States, by use

(Flasks)

Use	1975	1976	1977	1978	1979
Agriculture[1]	600	607	584	W	W
Amalgamation	7	11	W	--	--
Catalysts	838	1,264	1,545	W	548
Dental preparations	2,340	1,990	1,230	512	798
Electrical apparatus	16,971	27,498	29,180	(2)	(2)
Electrolytic preparation of chlorine and caustic soda	15,222	16,054	10,744	11,166	12,180
General laboratory use	335	595	406	420	410
Industrial and control instruments	4,598	5,067	5,221	(2)	(2)
Paint: Mildew proofing	6,928	7,845	8,365	8,956	9,979
Pharmaceuticals	445	60	W	W	W
Other[3]	1,750	2,909	2,589	(2)	(2)
Total known uses	50,034	63,900	59,864	48,766	45,442
Total unknown uses	804	970	1,395	--	--
Grand total	50,838	64,870	61,259	48,766	45,442

W Withheld to avoid disclosing company proprietary data; included in "Other."

[1] Includes fungicides and bactericides for industrial purposes.

[2] Due to format change, see table 6 for 1978 and 1979 data.

[3] Includes mercury used for installation and expansion of chlorine and caustic soda plants.

Table 6.—Mercury consumed in the United States in 1978-79

(Flasks)

Use	Primary	Redistilled	Secondary	Total
1978				
Chemicals and allied products:				
Chlorine and caustic preparation	11,166	--	W	11,166
Pigments	W	--	--	W
Catalysts	W	W	W	W
Laboratory uses	153	259	8	420
Plastic materials and synthetic (processing and resins)	W	--	--	W
Pharmaceuticals	W	W	--	W
Paint	8,956	W	--	8,956
Agricultural chemicals	W	--	--	W
Chemicals and allied products, n.e.c	W	W	--	W
Electrical and electronic instruments:				
Electrical lighting	422	487	--	909
Wiring devices and switches	2,020	1,158	--	3,178
Batteries	11,691	2,134	--	13,825
Other electrical and electronic equipment	41	W	--	41
Instruments and related products:				
Measuring and control devices	967	2,532	W	3,489
Dental equipment and supplies	W	512	W	512
Other instruments and related products	W	W	W	W
Other identified end uses:				
Refining lubricating oils	W	--	--	W
Other	W	--	--	W
Other	3,901	1,482	887	6,270
Total known uses	39,307	8,564	895	48,766
1979				
Chemicals and allied products:				
Chlorine and caustic preparation	12,180	--	W	12,180
Pigments	W	--	--	W
Catalysts	548	W	W	548
Laboratory uses	122	277	11	410
Plastic materials and synthetic (processing and resins)	W	--	--	W
Pharmaceuticals	--	W	--	W
Paint	9,979	W	--	9,979
Agricultural chemicals	W	--	--	W
Chemicals and allied products, n.e.c	W	W	W	W
Electrical and electronic instruments:				
Electrical lighting	W	511	--	511
Wiring devices and switches	2,147	1,066	--	3,213
Batteries	7,988	W	W	7,988
Other electrical and electronic equipment	W	W	--	W
Instruments and related products:				
Measuring and control devices	751	2,852	W	3,603
Dental equipment and supplies	W	793	W	793
Other instruments and related products	W	W	--	W
Other identified end uses:				
Refining lubricating oils	--	--	--	--
Other	--	--	--	--
Other	3,361	1,453	1,403	6,217
Total known uses	37,076	6,952	1,414	45,442

W Withheld to avoid disclosing company proprietary data.

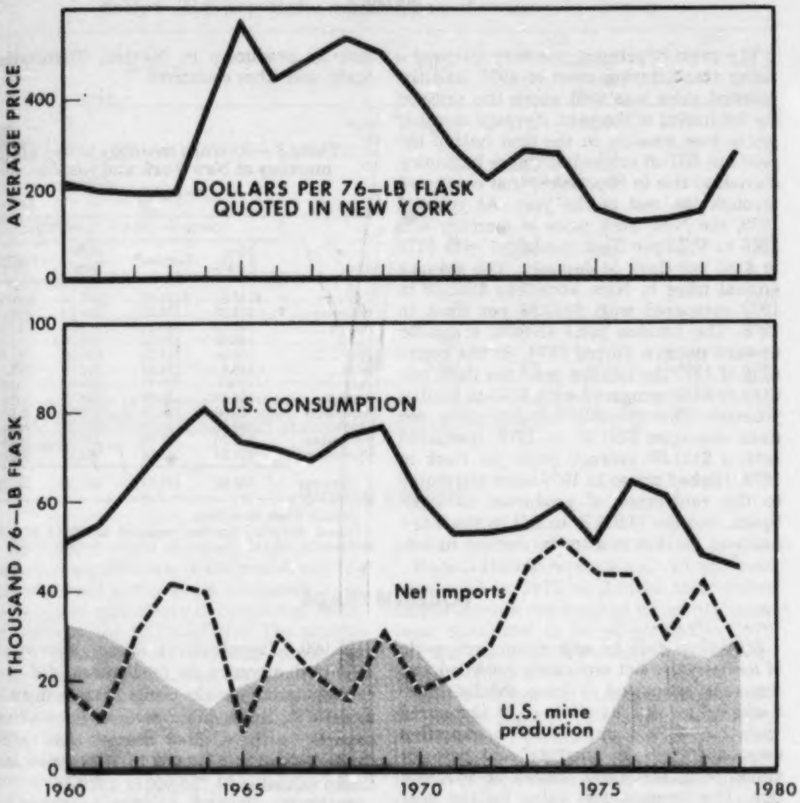

Figure 1.—Trends in production, consumption, and price of mercury.

Table 7.—Stocks of mercury, December 31

(Flasks)

Year	Producer	Consumer and dealer	Total
1975	4,858	20,691	25,549
1976	9,494	22,240	31,734
1977	11,275	22,903	34,178
1978	16,600	22,149	38,749
1979	9,181	18,401	27,582

PRICES

The price of primary mercury followed a rising trend during most of 1979, and the yearend price was well above the price at the beginning of the year. Average monthly prices rose steadily in the first half of the year but fell off somewhat before beginning a gradual rise in September that continued through the rest of the year. At yearend 1979, the New York price of mercury was $365 to $375 per flask compared with $175 to $185 per flask in January. The average annual price in New York was $281.10 in 1979 compared with $153.32 per flask in 1978. The London price showed a similar upward pattern during 1979. At the beginning of 1979 the London price per flask was $173 to $183 compared with $370 to $380 at yearend. The monthly London price per flask averaged $291.73 in 1979, compared with a $131.57 average price per flask in 1978. Higher prices in 1979 were attributed to the reluctance of producers in Italy, Spain, and the U.S.S.R. to sell in the international market and to the decline in output by producers in Mexico, Yugoslavia, Italy, and other countries.

Table 8.—Average monthly prices of mercury at New York and London

(Per flask)

	1978		1979	
	New York[1]	London[2]	New York[1]	London[2]
January	$147.81	$131.21	$186.14	$196.00
February	157.33	130.50	200.00	218.49
March	147.00	130.10	218.91	241.50
April	148.50	132.50	255.48	262.29
May	150.00	131.25	296.59	301.86
June	148.91	124.83	334.76	343.89
July	156.55	127.71	299.05	301.00
August	156.48	128.00	289.13	301.63
September	150.60	127.29	303.95	310.76
October	150.00	126.17	315.00	324.46
November	155.10	137.38	328.58	333.34
December	171.55	151.86	355.00	365.63
Average	153.32	131.57	281.10	291.73

[1] Metals Week, New York.

[2] Metal Bulletin, London; reported in terms of U.S. dollars.

FOREIGN TRADE

Statistical data on exports and reexports of mercury are not separately recorded, but they are estimated to have totaled 1,000 flasks valued at $281,000 in 1979. Compared with that of 1978, imports for consumption decreased 39% in quantity and 66% in value, to 26,448 flasks valued at $5.2 million. The average unit value for the year was $196.88 per flask compared with $125.68 per flask in 1978.

Mainland China, which became a significant exporter of mercury to the United States in 1976, recorded a six-fold increase in shipments from 575 flasks valued at $50,000 in 1977 to 3,329 flasks valued at $398,000 in 1978. In 1979, however, China recorded a 65% decline from the previous year's shipments, to 1,400 flasks valued at $183,000. Yugoslavia, a major source of imported mercury in past years, did not export mercury to the United States in 1978 and 1979. Japan, after several years of no exports to the United States, sent 4,428 flasks valued at $442,000 in 1978 and 7,960 flasks valued at $1,755,000 in 1979.

The U.S. rate of duty on mercury metal imports during 1979 was 12.5 cents per pound (or $9.50 per flask). The duty on waste and scrap mercury was suspended until June 30, 1981. These duty rates applied to imports from countries designated by the U.S. Government as "Most Favored Nation" (MFN).The statutory rate of 25 cents per pound (or $19 per flask) applied to other countries.

Table 9—U.S. imports for consumption[1] of mercury, by country

Country	1977		1978		1979	
	Flasks	Value (thousands)	Flasks	Value (thousands)	Flasks	Value (thousands)
Algeria	8,806	$1,148	8,751	$1,248	100	$34
Australia	469	33	--	--	--	--
Canada	1,708	211	895	130	3,943	783
China, Mainland	575	50	3,329	398	--	--
Dominican Republic	--	--	200	26	611	129
Finland	6	1	--	--	--	--
France	([2])	1	73	10	470	127
Germany, Federal Republic of	--	--	--	--	--	--
Italy	671	71	5,913	757	4,429	675
Japan	--	--	4,428	442	7,960	1,755
Mexico	4,668	486	813	70	403	60
Netherlands	--	--	369	59	25	4
Spain	8,790	894	13,923	1,723	8,507	1,640
Sweden	7	25	--	--	--	--
Turkey	--	--	2,999	377	--	--
Yugoslavia	3,050	343	--	--	--	--
Total	28,750	3,263	41,693	5,240	26,448	5,207

[1] General Imports: 1977—general imports and imports for consumption were the same; 1978—42,874 ($5,386,767), China, Mainland 4,010 flasks ($481,095), and Spain 14,423 ($1,786,774); 1979—28,818 ($5,659,206), China, Mainland 1,400 ($182,674), Italy 5,369 ($926,522), Japan 8,611 ($1,919,543), and Spain 8,356 ($1,621,083).

[2] Less than 1/2 unit.

WORLD REVIEW

Decreasing world demand, large inventories throughout much of the world, and low prices caused many large producers to remain closed and others to operate at reduced levels during 1978 and 1979. The international association of mercury producers, generally referred to as "Assimer", met periodically to review the mercury market situation. There were reports that the organization planned to try to bolster prices and to provide for more orderly marketing procedures.

Canada.—Canadian mining operations, which were suspended because of low prices in 1975, did not reopen in 1978 or 1979. Exports of mercury from stocks continued in these 2 years.

China, Mainland.—Sales in international markets were reduced in both years because of low price and weak demand.

Dominican Republic.—Mercury occurs in the gold-silver ore of the Pueblo Viejo gold mine on the island of Hispañola and is recovered by treating the dorè precipitate from the mine's cyanide plant in a 12-tube retort.

Italy.—Mining operations, which were suspended in 1977 as Societa Mercurifera Monte Amiata reorganized its mining activities, continued to be suspended in 1979. Sales of mercury reportedly were reduced because of low prices.

Spain.—Minas de Almaden Arrayanes, the largest producer, continued to sell at a reduced level because of low prices. Also, the company set base prices for its mercury that were good only for 48 hours and limited these prices to no more than 1 month ahead.

U.S.S.R.—Because of low prices, Soviet suppliers reportedly continued to be inactive in the international market in 1978 and 1979.

Yugoslavia.—Production of mercury was not reported in 1978 and 1979, and, if any did occur it is believed to have been very small. Yugoslavia's Idria mine, the country's principal producer, was closed early in 1977 due to low prices and declining grade of ore.

Table 10.—Mercury: World production, by country

(Flasks)

Country	1976	1977	1978p	1979e
Algeria	r30,915	r30,429	30,603	30,000
Australia	4	1	e2	2
Chile	13	20	--	--
China, Mainland	26,000	20,000	20,000	20,000
Czechoslovakia	r6,200	r5,950	6,370	6,300
Dominican Republic	--	495	500	500
Finland	383	630	1,145	1,200
Germany, Federal Republic of	3,191	2,872	2,437	2,500
Italy	22,278	406	87	--
Mexico	15,026	9,660	2,205	2,000
Spain	r42,729	35,013	31,039	35,000
Turkey	r4,899	4,686	5,020	5,000
U.S.S.R.e	56,000	58,000	60,000	61,000
United States	23,133	28,244	24,189	29,343
Yugoslavia	12,503	3,133	--	--
Total	r243,274	r199,539	183,597	192,845

eEstimate. pPreliminary. rRevised.

TECHNOLOGY

A method was developed to remove mercury from gases driven off sulfide ores during metallurgical operations.[7] Sulfur dioxide contained in gases developed during metallurgical operations is generally used to produce sulfuric acid, and the mercury in the sulfur dioxide tends to concentrate in the acid if not removed.

Development of a new mercury vapor arc lamp for use as a household light bulb continued by industry.[8] It was estimated that the new bulbs will last 5,000 hours, compared with 1,000 hours for ordinary incandescent bulbs, and that they will use only one-third as much electricity.

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[1] Physical scientist, Section of Nonferrous Metals.

[2] Flask as used throughout this chapter refers to the 76-pound flask.

[3] Environmental Protection Agency. Toxic Substances. Federal Register, v. 43, No. 208, Oct. 26, 1978, pp. 50140-50147.

[4] Chemical Week. Mercury and DDT Plague Rivers in Two States. V. 123, No. 25, Dec. 20, 1978, pp. 18-19.

[5] Brooks, H. C. Mercury Deposits of Oregon, Final Report to U.S. Bureau of Mines. October 1978, 44 pp.

[6] Yildiz, M., and E. H. Bailey. Mercury Deposits of Turkey. U.S. Geol. Survey Bull. 1456, 1978, 80 pp.

[7] Kuivala, A., and J. Poijarvi. Sulphuric Acid Washing Removes Mercury From Roaster Gases. Eng. and Min. J., v. 179, No. 10, October 1978, pp. 81-84.

[8] Business Week. From GE a $10 Bulb That Saves Money. June 25, 1979, pp. 35-36.

Mica

By Alvin B. Zlobik[1]

Sheet mica production was limited to a small quantity of handpicked, low-quality muscovite from North Carolina. Domestic scrap and flake mica production in 1978 increased 8% over that in 1977 while production in 1979 decreased 4% from that in 1978. Sales of ground mica during the 1978-79 period remained near the 1977 level of 122,000 tons.[2]

Fabrication of mica block decreased 46% in 1978 but increased 16% in 1979. Fabrication of mica film decreased 11% and 38% in 1978 and 1979, respectively. Consumption of mica splittings increased 34% to 5.5 million pounds in 1978 but decreased 12% to 4.9 million pounds in 1979.

Exports of all forms of unmanufactured mica decreased 10% to 9,200 tons in 1978, but increased 26% to 11,600 tons in 1979. Imports of all forms of mica increased 86% to 7,200 tons in 1978 and increased again to 10,300 tons in 1979.

Legislation and Government Programs.—The total government stockpile inventory of natural sheet mica was reduced to 30.1 million pounds by December 31, 1979. Sales of sheet mica by the General Service Administration (GSA) during 1978-79 totaled 1,688,000 pounds; this included 1,139,000 pounds of muscovite splittings and 549,000 pounds of phlogopite splittings. There were no sales of block or film mica in 1978 or 1979.

Table 1.—Salient mica statistics

	1975	1976	1977	1978	1979
United States:					
Production (sold or used by producing companies):					
Sheet mica thousand pounds	5	5	1	(1)	1
Value thousands	$3	$3	(1)	(1)	(1)
Scrap and flake mica[2] thousand short tons	132	123	129	139	134
Value[2] thousands	$5,205	$5,667	$7,039	$7,916	$7,708
Ground mica[2] thousand short tons	112	115	122	124	122
Value[2] thousands	$9,366	$10,207	$11,906	$12,979	$14,522
Consumption:					
Block thousand pounds	616	524	439	239	277
Value thousands	$1,581	$1,369	$952	$1,328	$1,841
Film thousand pounds	7	10	9	8	5
Value thousands	$27	$44	$38	$34	$25
Splittings thousand pounds	4,746	5,025	4,144	5,537	4,877
Value thousands	$2,634	$3,226	$2,718	$3,031	$3,248
Exports thousand short tons	6	8	10	9	12
Imports do	8	5	4	7	10
World production thousand pounds	[r]447,371	[r]465,231	[r]490,134	534,058	527,773

[r] Revised.

[1] Less than 1/2 unit.

[2] Data have been revised to exclude low-quality sericite.

Table 2.—Stockpile status, December 31, 1979[1]

(Thousand pounds)

Material	Goal	Total Inventory	Available for disposal	Sales (1978-79)
Stockpile grade:				
Block:				
Muscovite, Stained and better	6,188	4,997	--	--
Phlogopite	206	17	--	--
Film: Muscovite, 1st and 2d qualities	90	1,270	--	--
Splittings:				
Muscovite	12,631	20,934	1,913	1,139
Phlogopite	932	2,373	1,413	549

[1] In addition to the data shown, the stockpile contains the following: Material with goals (nonstockpile grade) includes 207,000 pounds muscovite block, Stained and better; 640 pounds muscovite film, 1st and 2d qualities; and 114,000 pounds phlogopite block. Other material, without goals, includes 178,000 pounds muscovite block, Stained or lower and 5,400 pounds muscovite film, 3d quality.

DOMESTIC PRODUCTION

Sheet Mica.—During the 1978-79 period, an estimated 1,500 pounds of low-quality and low-grade sheet muscovite was produced and sold locally in the Spruce Pine, N.C., area. This mica was handpicked as a byproduct during feldspar mining operations.

Scrap and Flake Mica.—U.S. production of scrap (flake) mica[2] in 1978 totaled 139,000 tons valued at $7.9 million. Production in 1979 was 134,000 tons valued at $7.7 million. North Carolina continued to lead the Nation in production accounting for 89,000 tons in 1978 and 84,000 tons in 1979. Remaining production came from Alabama, Connecticut, Georgia, New Mexico, Pennsylvania, South Carolina, and South Dakota. The majority of production was obtained by flotation of kaolin, feldspar, and mica ores.

Leading producers of scrap (flake) mica during the 1978-79 period were Harris Mining Co., Spruce Pine, N.C.; Mineral Industrial Commodities of America, Inc. (M.I.C.A.), Santa Fe, N. Mex.; Kings Mountain Mica Co., Kings Mountain, N.C.; Mineral Mining Corporation, Kershaw, S.C.; and Deneen Mica Company, Micaville, N.C.

Low-quality sericite production, used primarily in brick manufacturing, totaled 43,000 tons in 1978 and 41,000 tons in 1979; value was $119,000 and $107,000, respectively.

Ground Mica.—Production (sold or used) of ground mica showed little variation in quantity during the 1978-79 period. Value of ground mica in 1978 increased 9% above that in 1977 and, in 1979, increased 12% over that in 1978. In both 1978 and 1979, dry-ground mica constituted 89% and wet-ground mica accounted for 11% of total ground mica production.

As of December 31, 1977, Thompson, Weinman and Co., Cartersville, Ga., ceased mining and grinding operations of scrap mica. Depletion of the ore deposit was cited as the reason for discontinuing the operation.

In May 1979, the U.S. Gypsum Co., Chicago, Ill., purchased Diamond Mica Company, Spruce Pine, N.C., a leading producer of dry- and wet- ground mica.

GMS/Tanner Companies announced plans to open a major mica deposit in Arizona. The mica was to be ground by MAJAC mill and used initially in the joint cement industry.[4]

During 1979, thirteen companies operated 15 plants for ground scrap (flake) mica including high-quality sericite; of these, nine produced dry-ground, two produced wet-ground, and two produced both wet- and dry-ground material. Leading ground mica producers were Deneen Mica Company, Micaville, N.C.; Harris Mining Co., Spruce Pine, N.C.; Mineral Industrial Commodities of America, Inc. (M.I.C.A.), Santa Fe, N. Mex.; Kings Mountain Mica Co., Kings Mountain, N.C.; and Diamond Mica Co., Spruce Pine, N.C.

In 1978, low-quality ground sericite production, used principally in brick manufacturing, totaled 40,000 tons and was valued at $164,000. Production of this material remained the same in 1979; however, its value increased 9% to $179,000.

Table 3.—Mica sold or used by producers in the United States

Year and State	Sheet mica: Uncut punch and circle mica: Quantity (thousand pounds)	Sheet mica: Uncut punch and circle mica: Value (thousands)	Sheet mica: Uncut mica larger than punch and circle: Quantity (thousand pounds)[e]	Sheet mica: Uncut mica larger than punch and circle: Value (thousands)[e]	Sheet mica: Total sheet mica: Quantity (thousand pounds)[e]	Sheet mica: Total sheet mica: Value (thousands)[e]	Scrap and flake mica[1 2]: Quantity (thousand short tons)	Scrap and flake mica[1 2]: Value (thousands)
1975	--	--	5	$3	5	$3	132	$5,205
1976	--	--	5	3	5	3	123	5,667
1977	--	--	1	(3)	1	(3)	129	7,039
1978								
North Carolina	--	--	(3)	(3)	(3)	(3)	89	5,679
Other States[4]	--	--	--	--	--	--	50	2,238
Total	--	--	(3)	(3)	(3)	(3)	139	7,917
1979								
North Carolina	--	--	1	(3)	1	(3)	84	5,847
Other States[4]	--	--	--	--	--	--	50	1,861
Total	--	--	1	(3)	1	(3)	134	7,708

[e] Estimate.

[1] Includes finely divided mica recovered from mica and high-quality sericite schist, and mica that is a byproduct of feldspar, kaolin, and lithium beneficiation.

[2] Data have been revised to exclude low-quality sericite.

[3] Less than 1/2 unit.

[4] Includes Alabama, Connecticut, Georgia, New Mexico, Pennsylvania, South Carolina, and South Dakota.

Table 4.—Ground mica sold or used by producers in the United States, by method of grinding[1 2]

(Thousand short tons and thousand dollars)

Year	Dry-ground: Quantity	Dry-ground: Value	Wet-ground: Quantity	Wet-ground: Value	Total[3]: Quantity	Total[3]: Value
1975	101	6,537	11	2,829	112	9,366
1976	102	7,100	13	3,107	115	10,207
1977	107	8,233	15	3,673	122	11,906
1978	110	9,039	14	3,940	124	12,979
1979	108	10,193	14	4,329	122	14,522

[1] Domestic and some imported scrap.

[2] Data have been revised to exclude low-quality sericite.

[3] Data may not add to totals shown because of independent rounding.

CONSUMPTION AND USES

Sheet Mica.—Consumption of muscovite block (ruby and nonruby) in 1978 totaled 217,500 pounds, a decrease of 47% from that in 1977. However, in 1979, consumption of this same material increased 22% over the 1978 total. The increase in 1979 consumption took place mainly in larger sizes, grades 5 1/2 and larger.[8] Consumption of grade 6 and smaller decreased 21% from the total in 1978; this reflected the continuing movement of smaller grade fabrication overseas.

In 1978 and 1979, vacuum tubes accounted for 70% and 64%, respectively, of the total muscovite block fabricated. The remaining fabricated block was used in capacitors and other uses (27% and 34%) and in gage glass and diaphragms (3% and 2%). During the 1978-79 period, Stained-quality muscovite block was in greatest demand and accounted for about 70% of consumption, followed by Lower than Stained, about 27% and Good Stained or better 2% to 3%. During 1978 and 1979, consumption of No. 4 grade and larger accounted for 13% and 16%, respectively; No. 5, 17% and 16%; No. 5 1/2, 4% and 25%; No. 6, 58% and 31%; and smaller than No. 6, 8% and 12%.

Mica film consumption in 1978 decreased 16% from that in 1977 to 7,800 pounds and decreased further in 1979 to 4,900. These decreases could be attributed to increased fabrication overseas, and substitution of other materials. First-quality film comprised about 40% of the total amount fabricated; second-quality accounted for 38% and 49% fabricated in 1978 and 1979, respectively.

Muscovite block and film was consumed by nine companies in seven States. There were two consuming plants in North Carolina and in Massachusetts with one each in New Jersey, New York, Ohio, Pennsylvania, and Virginia. New York, Pennsylvania, and Virginia combined consumed 83% of the total block and film used for fabrication in 1978 and 82% in 1979.

Phlogopite block fabrication totaled 21,300 and 11,800 pounds in 1978 and 1979, respectively, compared with 26,100 pounds in 1977. The primary reason for the decreases was difficulty in obtaining raw material. In both years phlogopite was consumed by 6 companies in 5 States.

Consumption of mica splitting in 1978 totaled 5.5 million pounds, an increase of 34% over that in 1977. Consumption decreased in 1979 to 4.9 million pounds. For 1978 and 1979, muscovite splittings, mainly from India, represented 97% of total consumption; the remainder was phlogopite splittings from Madagascar. No significant changes in phlogopite splitting consumption occurred in 1978-79. During 1979, splittings were fabricated into various built-up mica products by 11 companies operating 12 plants in 9 States.

The large increase in phlogopite splittings value from 1978 to 1979 shown in table 7 was caused by addition of a company to the survey and to increased prices for raw material.

Built-up Mica.—This mica-base product was made by mechanical or hand setting of overlapping splittings and alternate layers of binders and splittings. The primary use was as electrical insulating material. Primary built-up mica products include molding plate, segment plate, heater plate, flexible (cold) plate, and tape. Data pertaining to these end uses are shown in table 8.

Reconstituted Mica (Mica Paper).—In 1978 and 1979, six companies consumed 7.1 and 6.4 million pounds, respectively, of scrap mica to produce 4.6 and 4.2 million pounds, respectively, of mica paper. The principal sources of scrap mica were India and Brazil. Primary end uses for mica paper were the same as those for built-up mica. Manufacturing companies were General Electric Co., Schenectady, N.Y.; U.S. Samica Corp., Rutland, Vt.; Kirkwood-Acim Corp., Hempstead, N.Y.; Essex Group, United Technologies Corp., New Market, N.H.; Corona Film Inc., West Townsend, Mass.; and Proctor-Silex SCM Corp., Mount Airy, N.C.

Ground Mica.—Ground mica sold or used in 1978 and 1979 totaled 124,000 and 122,000 tons, respectively, showing little change from that in 1977. The principal end uses in 1979 were joint cement (52%), paint (16%), and rubber (3%). Miscellaneous end uses, including ground mica used in oil well drilling muds and roofing, comprised the remaining 29%.

Consumption of low-quality ground sericite, used principally in brick manufacturing, totaled about 40,000 tons in 1978 and 1979. The bulk of this sericite, used as a coloring agent and as filler in brick, was produced in South Carolina.

Table 5.—Fabrication of muscovite ruby and nonruby block and film mica and phlogopite block mica, in the United States in 1978 and 1979, by quality and end-product use

(Pounds)

Variety, form, and quality	Electronic uses								Nonelectronic uses							
	Capacitors		Tubes		Other		Total		Gage glass and diaphragms		Other		Total		Grand total	
	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979
Muscovite:																
Block:																
Good Stained or better	300	300	500	--	1,100	500	1,900	800	4,800	5,400	(1)	200	4,800	5,600	6,700	6,400
Stained	--	--	120,000	12,400	28,200	37,900	148,200	50,300	1,800	1,000	5,000	6,000	6,800	7,000	155,000	57,300
Lower than Stained[2]	--	--	31,700	157,200	7,500	10,500	39,200	167,700	--	(1)	16,600	33,900	16,600	33,900	55,800	201,600
Total	300	300	152,200	169,600	36,800	48,900	189,300	218,800	6,600	6,400	21,600	40,100	28,200	46,500	217,500	265,300
Film:																
1st quality	3,200	1,900	--	--	--	--	3,200	1,900	--	--	--	--	--	--	3,200	1,900
2d quality	3,000	2,400	--	--	--	--	3,000	2,400	--	--	--	--	--	--	3,000	2,400
Other quality	1,600	600	--	--	--	--	1,600	600	--	--	--	--	--	--	1,600	600
Total	7,800	4,900	--	--	--	--	7,800	4,900	--	--	--	--	--	--	7,800	4,900
Block and film:																
Good Stained or better[3]	6,500	4,600	500	--	1,100	500	8,100	5,100	4,800	5,400	(1)	200	4,800	5,600	12,900	10,700
Stained[4]	1,600	600	120,000	12,400	28.200	37,900	149,800	50,900	1,800	1,000	5,000	6,000	6,800	7,000	156,600	57,900
Lower than Stained	--	--	31,700	157,200	7,500	10,500	39,200	167,700	--	(1)	16,500	33,900	16,600	32,900	55,800	201,600
Total	8,100	5,200	152,200	169,600	36,800	48,900	197,100	223,700	6,600	6,400	21,600	40,100	28,200	46,500	225,300	270,200
Phlogopite: Block (all qualities)	--	--	--	--	1,000	--	1,000	--	--	--	20,300	11,800	20,300	11,800	21,300	11,800

[1] Insignificant.
[2] Includes punch mica.
[3] Includes 1st- and 2d-quality film.
[4] Includes other-quality film.

Table 6.—Fabrication of muscovite ruby and nonruby block and film mica in the United States in 1978 and 1979, by quality and grade

(Pounds)

Form, variety, and quality	No. 4 and larger		No. 5		No. 5 1/2		No. 6		Other[1]		Total	
	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979
Block:												
Ruby:												
Good Stained or better	2,300	2,800	1,700	1,600	400	500	900	600	--	--	5,300	5,500
Stained	11,900	18,100	29,800	34,500	5,300	63,600	100,300	57,000	--	3,900	147,300	177,100
Lower than Stained	5,600	5,800	1,900	3,000	2,800	2,200	23,400	23,200	12,700	22,400	46,400	56,600
Total	19,800	26,700	33,400	39,100	8,500	66,300	124,600	80,800	12,700	26,300	199,000	239,200
Nonruby:												
Good Stained or better	700	800	700	500	--	--	--	--	--	--	1,400	1,300
Stained	5,000	6,400	--	--	900	300	1,800	1,700	--	--	7,700	8,400
Lower than Stained	1,700	8,500	2,000	2,400	--	--	1,700	900	4,000	4,600	9,400	16,400
Total	7,400	15,700	2,700	2,900	900	300	3,500	2,600	4,000	4,600	18,500	26,100
Total block (ruby and nonruby)	27,200	42,400	36,100	42,000	9,400	66,600	128,100	83,400	16,700	30,900	217,500	265,300
Film:												
Ruby:												
1st quality	200	300	800	400	400	200	600	400	--	--	2,000	1,300
2d quality	200	300	700	400	1,400	900	400	400	--	--	2,700	2,000
Other quality	--	--	--	--	--	--	--	--	1,600	600	1,600	600
Total	400	600	1,500	800	1,800	1,100	1,000	800	1,600	600	6,300	3,900
Nonruby:												
1st quality	--	--	--	--	400	300	800	300	--	--	1,200	600
2d quality	--	--	--	--	300	400	--	--	--	--	300	400
Other quality	--	--	--	--	--	--	--	--	--	--	--	--
Total	--	--	--	--	700	800	800	300	--	--	1,500	1,000
Total film (Ruby and Nonruby)	400	600	1,500	800	2,500	1,900	1,800	1,100	1,600	600	7,800	4,900

[1] Figures for block mica include all smaller than No. 6 grade and punch mica.

Table 7.—Consumption and stocks of mica splittings in the United States, by source

(Thousand pounds and thousand dollars)

	India		Madagascar		Total[1]	
	Quantity	Value	Quantity	Value	Quantity	Value
Consumption:						
1975	4,625	2,529	120	104	4,746	2,634
1976	4,903	3,084	122	142	5,025	3,226
1977	3,979	2,525	165	193	4,144	2,718
1978	5,371	2,837	166	194	5,537	3,031
1979	4,714	2,745	163	503	4,877	3,248
Stocks on Dec. 31:						
1975	3,465	NA	44	NA	3,510	NA
1976	3,166	NA	124	NA	3,290	NA
1977	3,130	NA	68	NA	3,198	NA
1978	2,695	NA	76	NA	2,771	NA
1979	2,331	NA	110	NA	2,441	NA

NA Not available.

[1] Data may not add to totals shown because of independent rounding.

Table 8.—Built-up mica[1] sold or used in the United States, by product

(Thousand pounds and thousand dollars)

Product	1977		1978		1979	
	Quantity	Value	Quantity	Value	Quantity	Value
Molding plate	1,227	2,751	1,439	3,062	1,549	3,951
Segment plate	1,408	3,787	1,558	3,892	1,558	4,423
Heater plate	172	249	165	329	168	485
Flexible (cold)	617	1,804	577	1,914	634	2,276
Tape	775	3,414	878	3,018	744	2,721
Other	346	1,246	324	1,301	402	1,801
Total[2]	4,545	13,251	4,941	13,516	5,055	15,657

[1] Consists of alternate layers of binder and irregularly arranged and partly overlapped splittings.

[2] Data may not add to totals shown because of independent rounding.

Table 9.—Ground mica sold or used by producers in the United States, by end use

(Thousand short tons and thousand dollars)

Use	1977		1978		1979	
	Quantity	Value	Quantity	Value	Quantity	Value
Roofing	3	200	7	635	W	W
Rubber	5	1,202	4	1,044	4	1,177
Paint	25	2,703	21	2,367	19	2,233
Joint cement	57	4,481	58	4,898	63	6,315
Other uses[1]	32	3,320	34	4,034	36	4,796
Total[2]	122	11,906	124	12,979	122	14,522
Brick and other[3]	41	291	40	164	40	179

W Withheld to avoid disclosing company proprietary data; included with "Other uses."

[1] Includes mica used for agricultural products, molded electric insulation, plastics, welding rods, well drilling, textile and decorative coating, wallpaper, and uses indicated by symbol W.

[2] Data may not add to totals shown because of independent rounding.

[3] Low-quality sericite.

STOCKS

Reported yearend consumer stocks of sheet mica were 3.1 million pounds in 1978 and 2.8 million pounds in 1979. Splittings comprised 90% and 87% of the totals in 1978 and 1979, respectively; the remainder was block. Only a small quantity of film was reported in stock in 1978 and 1979.

Producer stocks of ground mica at yearend 1978 and 1979 were small because of good demand for the product.

PRICES

The average reported values of muscovite sheet mica in 1979, based on consumption data, were as follows: block, $6.47 per pound; film, $5.21 per pound; and splittings, $0.58 per pound. The average values of phlogopite sheet mica for 1979 were $6.36 per pound for block and $3.09 per pound for splittings. Compared with 1978 average reported values, muscovite block increased 11%, muscovite film increased 19%, and muscovite splittings increased 9%. Compared with 1978 phlogopite sheet mica values, block increased 134% in 1979 while splittings increased 164%.

The average value of scrap (flake) mica, including high-quality sericite, was $57.52 per ton in 1979, with no significant change from that in 1978. The average value per ton for North Carolina scrap (flake) mica, predominantly a flotation product, was $64.00 in 1978 and $66.00 in 1979.

Low-grade, unground sericite, primarily from South Carolina, averaged $2.75 per ton in 1978 and $2.61 per ton in 1979.

The average of reported prices for ground mica in 1978 and 1979 are shown in table 10.

Table 10.—Averages of reported prices for dry- and wet-ground mica sold or used by U.S. producers in 1978 and 1979

(Dollars per short ton)

	1978	1979
Wet-ground	281	309
Dry-ground	82	94
End uses:		
Roofing	91	W
Rubber	261	294
Paint	113	118
Joint cement	84	100
Other uses[1]	119	133

W Withheld to avoid disclosing company proprietary data; included in "Other uses."

[1] Includes mica used for agricultural products, molded electrical insulation, plastics, welding rods, well drilling, textile and decorative coatings, wallpaper, and other uses.

FOREIGN TRADE

Exports of unmanufactured mica are placed in one category which includes block, film, splittings, and waste; sometimes, ground mica exports are also placed in this category. Exports of mica in this category totaled 3,400 tons valued at $2.0 million in 1978, and 5,800 tons valued at $1.7 million in 1979. In 1978, Japan was the leading country of destination with 750 tons valued at $691,000. In 1979, the United Kingdom was the primary country of destination accounting for 2,000 tons valued at $577,000.

Exports listed as ground mica totaled 5,800 tons valued at $1.2 million in 1978; exports in 1979 remained at 5,800 tons but were valued at $1.4 million. Canada was the leading country of destination in 1978 and 1979 with 2,900 tons valued at $500,000 and 2,600 tons valued at $463,000, respectively.

Imports of all classes of mica increased 86% to 14.5 million pounds in 1978, mainly because of a substantial increase in mica splittings imports and large shipments of ground mica from Canada. Imports of all classes of mica in 1979 rose 42% to 20.6 million pounds. The principal cause for this large increase was the more than doubling of ground mica imports from Canada, from about 1,700 tons ($264,000) in 1978 to about 4,500 tons ($742,000) in 1979.

Tables 11 thru 13 list U.S. mica imports, exports and value.

Table 11.—U.S. exports of mica and manufactures of mica in 1978 and 1979, by country

Destination	Mica, unmanufactured, including block, film, splittings, and waste: Quantity (short tons)		Value (thousands)		Mica, ground or pulverized: Quantity (short tons)		Value (thousands)		Mica, cut or stamped, built-up mica: Value (thousands)	
	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979
Argentina	6	204	$22	$58	1	--	$1	--	$23	$25
Australia	65	200	26	56	22	13	15	$7	75	105
Bahamas	--	--	--	--	--	--	--	--	34	52
Brazil	50	16	14	4	3	1	1	1	514	407
Canada	384	561	108	159	2,908	2,582	501	463	1,758	2,254
Chile	40	--	9	--	6	27	1	5	3	11
Colombia	4	3	1	1	33	82	12	34	6	13
Egypt	21	119	12	45	99	107	20	21	--	--
El Salvador	60	--	18	--	4	--	1	--	--	9
France	8	160	23	46	333	460	87	104	22	4
Germany, Federal Republic of	73	248	60	73	240	259	50	71	154	341
Guatemala	--	8	--	3	38	30	29	22	2	--
Haiti	5	--	4	--	--	--	--	--	4	112
Honduras	7	5	2	1	28	25	3	3	4	3
Hong Kong	--	12	--	3	--	9	--	2	244	64
Hungary	39	--	196	--	--	--	--	--	--	--
Israel	54	--	17	--	44	--	9	--	1	6
Italy	73	77	37	25	215	268	47	70	111	265
Japan	746	764	691	216	169	374	84	165	453	247
Korea, Republic of	16	168	11	48	108	7	28	3	--	1
Mexico	26	28	11	8	724	574	62	118	399	333
Netherlands	1	--	9	--	131	188	32	52	10	13
Netherland Antilles	--	--	--	--	--	--	--	--	36	5
Nicaragua	48	--	14	--	--	--	--	--	--	--
Nigeria	27	40	9	15	--	--	--	--	--	--
Norway	--	4	--	1	60	60	7	8	2	10
Peru	--	190	--	66	14	35	5	15	13	1
Poland	194	--	55	--	--	--	--	--	--	--
Portugal	--	--	--	--	--	--	--	--	35	22
Qatar	--	23	--	9	60	--	21	--	--	--
Saudi Arabia	20	--	8	--	95	--	16	--	85	14
Singapore	49	24	17	7	13	79	5	6	11	16
South Africa, Republic of	1	--	1	--	1	--	1	--	66	116
Spain	427	558	183	158	22	37	6	10	151	153
Taiwan	125	62	36	18	2	3	2	1	47	119
Trinidad	43	5	10	1	42	--	31	--	2	--
United Kingdom	427	2,085	315	577	28	57	19	32	252	306
Venezuela	283	71	107	26	267	378	68	83	72	101
Other	92	242	25	49	138	191	40	78	108	91
Total	3,414	5,827	2,051	1,673	5,848	5,846	1,204	1,374	4,697	5,224

Table 12.—U.S. imports for consumption of mica, by kind and country for 1978 and 1979

Year and country	Waste and scrap: Phlogopite: Quantity (pounds)	Waste and scrap: Phlogopite: Value (thousands)	Waste and scrap: Other: Quantity (pounds)	Waste and scrap: Other: Value (thousands)	Block mica: Quantity (pounds)	Block mica: Value (thousands)	Other: Muscovite: Quantity (pounds)	Other: Muscovite: Value (thousands)	Other: Other, n.e.c.: Quantity (pounds)	Other: Other, n.e.c.: Value (thousands)
1976	2,836	$3	4,209,738	$202	347,828	$675	3,440	$32	1,303,425	$234
1977	2,600	1	2,345,678	111	463,879	653	8,819	31	1,706,689	304
1978:										
Belgium	--	--	--	--	--	--	4,409	(1)	--	--
Brazil	--	--	212,000	10	166,334	241	1,782,090	251	--	--
Canada	--	--	--	--	790	2	15,882	4	--	--
Germany, Federal Republic of	--	--	939,116	46	176	1	--	--	--	--
India	--	--	69,861	3	66,909	332	2,770,035	373	--	--
Japan	--	--	--	--	--	--	160,936	8	--	--
Madagascar	--	--	--	--	13,558	27	38,070	28	--	--
Tanzania	--	--	--	--	162	2	2,156	35	--	--
United Kingdom	--	--	--	--	--	--	2,814	71	--	--
Total	--	--	1,220,977	59	247,929	605	4,771,392	770	--	--
1979:										
Belgium	--	--	--	--	--	--	--	--	55,115	3
Brazil	--	--	--	--	181,424	318	--	--	1,055,818	302
Canada	--	--	--	--	--	--	--	--	41,356	5
Germany, Federal Republic of	--	--	--	--	--	--	--	--	39,462	9
India	--	--	176,368	9	54,325	400	--	--	4,888,995	431
Madagascar	--	--	--	--	7,264	18	--	--	238,760	58
Sri Lanka	--	--	--	--	--	--	--	--	44,112	4
Tanzania	--	--	--	--	467	16	--	--	1,178	8
United Kingdom	--	--	--	--	--	--	--	--	1,092	26
Total	--	--	176,368	9	243,480	752	--	--	6,365,888	846

Year and country	Splittings: Quantity (pounds)	Splittings: Value (thousands)	Not cut or stamped not over 0.006 inch in thickness: Quantity (pounds)	Not cut or stamped not over 0.006 inch in thickness: Value (thousands)	Cut or stamped: Not over 0.006 inch in thickness: Quantity (pounds)	Cut or stamped: Not over 0.006 inch in thickness: Value (thousands)	Cut or stamped: Over 0.006 inch in thickness: Quantity (pounds)	Cut or stamped: Over 0.006 inch in thickness: Value (thousands)
1976	1,710,973	561	100	1	74,413	789	107,799	233
1977	2,140,733	683	7,457	9	81,525	1,170	76,955	311
1978:								
Canada	--	--	--	--	--	--	4,065	24
Germany, Federal Republic of	--	--	--	--	2,855	6	400	2
Haiti	--	--	--	--	1,337	20	--	--
India	3,742,562	1,189	--	--	90,614	1,323	67,731	310
Italy	--	--	(2)	(2)	--	--	--	--
Japan	611	1	--	--	--	--	320	3
Korea, Republic of	--	--	--	--	13	1	--	--
Laos	--	--	--	--	4	2	--	--
Madagascar	24,264	18	--	--	--	--	--	--
Pakistan	62,500	20	--	--	--	--	--	--
Spain	--	--	--	--	--	--	252	1
Taiwan	--	--	--	--	68	2	--	--
United Kingdom	6,000	26	--	--	1,685	82	4	(1)
Total	3,835,937	1,254	--	--	96,576	1,436	72,772	340
1979:								
Canada	--	--	--	--	470	5	3,172	21
France	23,038	21	--	--	5	1	--	--
Germany, Federal Republic of	--	--	--	--	10	4	400	2
Gibraltar	--	--	--	--	216	9	--	--
Haiti	--	--	--	--	222	3	--	--
Hong Kong	--	--	--	--	1,451	8	826	4
India	[3]3,738,591	[3]1,336	[3]921	[3]2	92,297	953	104,668	376
Japan	--	--	--	--	10	(1)	449	2
Korea, Republic of	--	--	--	--	395	10	67	(1)
Madagascar	166,226	163	--	--	--	--	--	--
Mexico	--	--	--	--	--	--	53	1
Netherlands	--	--	--	--	--	--	13	2
Pakistan	44,250	15	--	--	--	--	--	--
Taiwan	--	--	--	--	48	2	--	--
United Kingdom	5,100	12	--	--	1,598	52	77	8
Total	3,977,205	1,547	921	2	96,717	1,047	109,725	416

See footnotes at end of table.

Table 12.—U.S. imports for consumption of mica, by kind and country for 1978 and 1979 —Continued

Year and country	Mica plates and built-up mica		Ground or pulverized		Articles not especially provided for of mica	
	Quantity (pounds)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (pounds)	Value (thousands)
1976	848,758	1,276	273	48	39,344	285
1977	645,359	1,045	146	29	23,870	126
1978:						
Belgium	584,728	847	--	--	--	--
Canada	3,421	21	1,704	248	4,823	31
France	24,728	6	21	9	--	--
Germany, Federal Republic of	34,436	99	(1)	2	23	2
India	133,939	224	--	--	3,742	29
Japan	7,672	23	--	--	14	2
Mexico	--	--	--	--	10	1
Netherlands	--	--	--	--	208	18
United Kingdom	1,977	7	3	4	154	5
Total	790,896	1,237	1,728	268	8,969	83
1979:						
Austria	--	--	--	--	24	(1)
Belgium	357,367	744	--	--	--	--
Canada	4,550	37	4,264	569	4,251	33
France	2,596	6	20	23	--	--
Germany, Federal Republic of	8,083	42	5	2	26	2
Hong Kong	1,366	9	--	--	988	3
India	142,273	285	--	--	3,997	37
Israel	--	--	--	--	68	(1)
Japan	33,738	173	18	17	1,237	4
Netherlands	--	--	--	--	236	40
United Kingdom	2,715	10	226	182	75	3
Singapore	837	7	--	--	--	--
Switzerland	5,432	31	--	--	4	(1)
Total	558,957	1,344	4,533	743	10,901	122

[1] Less than 1/2 unit.

[2] Official trade returns report an import of unmanufactured mica, not cut or stamped, not over 0.006 inch in thickness from Italy in 1978, but the entry is apparently in error.

[3] Official trade returns report an additional 62,500 pounds valued at $17,000 from India in this category. The entry was in error and has been added to splittings from India.

Table 13.—Summation of U.S. mica trade data

	EXPORTS					
	Unmanufactured[1]		Ground or pulverized		Manufactured, cut or stamped, built-up	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1975	[2]5,489	[2]$3,154	NA	NA	566	$3,950
1976	[2]7,225	[2]3,477	NA	NA	1,241	3,776
1977	[2]9,101	[2]3,557	NA	NA	506	3,267
1978	3,414	2,051	5,848	$1,204	NA	4,697
1979	5,827	1,673	5,846	1,374	NA	5,224

	IMPORTS							
	Uncut sheet[3] and punch		Scrap		Ground or pulverized		Manufactured, cut or stamped, built-up	
	Quantity (thousand pounds)	Value (thousands)	Quantity (thousand pounds)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (thousand pounds)	Value (thousands)
1975	4,699	$1,615	10,672	$356	101	$22	1,078	$1,994
1976	3,366	1,503	4,213	202	273	48	1,070	2,583
1977	4,328	1,680	2,348	112	146	29	827	2,652
1978	8,855	2,629	1,221	59	1,728	263	969	3,096
1979	10,587	3,147	176	9	4,533	743	776	2,929

NA Not available.
[1] Includes block, film, splittings, and waste. Sometimes shipments of ground mica are placed in this category.
[2] Includes ground mica.
[3] The "Other" classification included in this category often contains scrap mica shipments.

WORLD REVIEW

World production of mica increased 9% to 534 million pounds in 1978 whereas production in 1979 decreased slightly to 528 million pounds. India led the world in production of sheet mica. The United States remained world leader in production of scrap (flake) mica.

India.—In 1978, mica exporters experienced some difficulties moving their cargo to and through the port of Calcutta; the port handled about 80% of India's mica exports. Problems included slow movement of railcars from the mines to the port, mismanagement at the port, and frequent cargo shutouts by shipping lines.[6]

The Soviet Union was India's largest mica customer in 1978 with purchases totaling about $26.9 million. From January through June, 1979, the Mica Trading Corporation of India (MITCO), booked orders with the U.S.S.R. for about 1.5 million pounds valued at approximately $12.2 million. MITCO also contracted with Minex, the Polish State Trading Corporation, to supply mica worth about $800,000, from January through June, 1979; additional contracts were anticipated.[7]

In 1979, the West German firm AEG Isolier Kassel (AIK) agreed to supply technical assistance to the Mica Trading Corporation of India (MITCO) in the manufacture of mica-paper-based insulating materials. AIK also agreed to purchase the insulating materials provided that delivery time, quality, and price were acceptable. Commercialization of mica paper production was expected to take about two years; until that time, imported mica paper was to be used to manufacture the insulating materials in India.[8]

Poland.—Poland expressed interest in buying mica from Pakistan. Should an agreement be reached, purchases would be for sheet mica and not for raw, untrimmed mica because Poland does not have available skilled labor to convert the raw mica into sheet form.[9]

South Africa.—Gelletich Mining Industries (Pty), Ltd., initiated a new production process for separating mica from waste rock dumps, which should increase production by 75%. Seperation of mica is accomplished by sliding sized incoming material down a wet plate. The higher aspect ratio of the mica, compared with the associated material, enables it to cling to the plate by surface tension while the waste material passes. The process will also increase the recovery rate of the primary mica production facility.[10] [11]

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[1] Physical scientist, Section of Nonmetallic Minerals.

[2] Short tons are used throughout unless otherwise stated.

[3] Production of high-quality sericite is included in the totals; however, figures for low-quality sericite, used principally for brick manufacturing, are not included.

[4] Industrial Minerals (London), No. 143 , August 1979, p. 17.

[5] In sheet mica grading, the lower the grade number, the larger the size (area), that is, No. 1 grade is larger than No. 2 grade, etc.

[6] Industrial Minerals (London), No. 134, November 1978, p. 11.

[7] Seshadri, G.R. Mining Annual Review - India. Mining Journal (London), June 1979, p. 439.

[8] Industrial Minerals (London), No. 146, November 1979, p. 15.

[9] Industrial Minerals (London), No. 135, December 1978, p. 10.

[10] Mining Journal (London), v. 292, No. 7504, June 15, 1979, p. 466.

[11] Industrial Minerals (London), No. 139, April 1979, p. 33.

Table 14.—Mica: World production, by country

(Thousand pounds)

Country[1]	1976	1977	1978	1979[e]
Argentina:				
Sheet	725	666	686	650
Waste, scrap, etc.	5,051	4,057	4,376	4,400
Brazil[2]	6,171	4,310	7,055	6,200
Colombia[e]	90	100	--	--
Egypt	[r] [e]22	190	[e]190	--
France[e]	[r]7,200	[r]7,700	8,000	7,700
India:				
Exports:				
Block	1,962	2,423	3,208	3,100
Film and disk	322	278	271	300
Splittings	7,791	7,595	9,229	9,250
Scrap	17,758	21,954	[e]21,800	26,450
Powder	20,366	16,546	[e]18,100	18,500
Manufactured	664	1,036	800	950
Domestic consumption, all forms[e]	[r]24,500	[r]24,732	25,100	25,600
Total	[r]73,363	[r]74,564	78,508	84,150
Korea, Republic of (sericite)	11,715	22,339	37,309	37,000
Madagascar (phlogopite):				
Block	15	3,303	3,452	3,750
Splittings	137			
Scrap	26			
Mexico	2,873	1,700	884	900
Mozambique (including scrap)[2]	1,984	1,764	1,984	2,000
Nepal[e]	10	10	10	10
Norway (including scrap)[2]	6,797	6,213	6,195	6,300
Peru	20	20	128	110
South Africa, Republic of:				
Sheet	(3)	(3)	(3)	(3)(4)
Scrap	5,247	6,927	5,604	[4]3,792
Spain	[e]1,100	--	--	--
Sri Lanka (scrap)	302	[e]220	309	300
Sudan	1,213	[e]880	2,200	2,200
Tanzania, sheet	15	15	13	10
U.S.S.R. (all grades)[e]	95,000	97,000	99,000	100,000
United States:				
Sheet[e]	5	1	(3)	1
Scrap and flake[5]	[r]246,000	258,000	278,000	[4]268,000
Yugoslavia	150	155	[e]155	300
Total[5]	465,231	490,134	534,058	527,773

[e] Estimate. [r] Revised. NA Not available.

[1] In addition to the countries listed, Pakistan, the People's Republic of China, Romania, South-West Africa, Sweden, and Zimbabwe are known to produce mica, but available information is inadequate to make reliable estimates of output levels.

[2] Exports.

[3] Less than 1/2 unit.

[4] Reported figure.

[5] Revised data. Excludes U.S. production of low-quality sericite.

Molybdenum

By John T. Kummer[1]

The molybdenum market remained strong during 1978 and 1979 with estimated world demand exceeding mine output during both years. Limitations on supply, continued producer price increases, and low inventory levels characterized the industry. Strikes at major Canadian mines also contributed to the tight worldwide availability, particularly in 1979. Domestic production exhibited steady growth as a major mine moved closer to capacity output. The United States accounted for 60% and 63% of world output in 1978 and 1979, respectively, and exported slightly over one half of its production, chiefly to Western Europe and Japan. Despite the supply tightness, U.S. industrial demand for molybdenum grew to levels comparable to the high-demand years of 1973 and 1974. Mining firms were very active in exploring and evaluating molybdenum prospects. Several properties, primarily in the United States and Canada, were committed for development; these will increase world supply significantly in the early and mid 1980's.

Legislation and Government Programs.—The General Services Administration (GSA) shipped the last of the molybdenum from the Government stockpile excesses in 1977. Present stockpile goals set by GSA do not include molybdenum materials.

During 1979, the U.S. Congress considered legislation that would determine which Federal Lands in Alaska would be opened for potential mineral exploitation. The development of a large molybdenum deposit in southeastern Alaska would likely be contingent on provisions in an Alaskan Lands Act, which had not been enacted in final form by yearend.

Table 1.—Salient molybdenum statistics

(Thousand pounds of contained molybdenum and thousand dollars)

	1975	1976	1977	1978	1979
United States:					
Concentrate:					
Production	105,980	113,233	122,408	131,843	143,967
Shipments	105,170	114,527	124,974	130,694	143,504
Value	$250,328	$333,494	$450,421	$607,950	[1]871,068
Consumption	90,046	84,966	91,941	96,375	103,152
Imports for consumption	2,567	2,093	1,976	2,705	2,329
Stocks, Dec. 31: Mine and plant	10,680	9,390	9,161	8,980	9,530
Primary products:					
Production	87,501	83,970	90,520	96,052	101,754
Shipments	89,789	99,144	100,626	105,921	109,419
Consumption	51,743	50,448	54,557	61,091	60,388
Stocks, Dec. 31: Producers	22,863	13,210	10,141	7,986	8,502
World: Production	[r]180,288	[r]195,473	[r]209,724	[p]220,922	[e]227,097

[e] Estimate. [p] Preliminary. [r] Revised.

[1] For 1979, value is based on the average domestic price of molybdenum in technical-grade molybdic oxide ($6.07 per pound) sold by the major domestic producer.

DOMESTIC PRODUCTION

The growth in domestic mine production of molybdenum in 1978 and 1979 was primarily the result of increased output from AMAX Inc.'s Henderson mine in Colorado. Output was also buoyed by a stronger copper market, which began in late 1978, and a generally greater emphasis placed on byproduct molybdenum recovery among the copper producers. In both 1978 and 1979, production from the three primary molybdenum mines (Climax, Henderson, and Questa) accounted for 68% of the annual U. S. output. Byproduct and coproduct sources, chiefly 16 porphyry copper mines, supplied the remainder; less than 0.5% was recovered from tungsten and uranium mining operations.

Tungsten and small amounts of tin and pyrite were recovered as byproducts from molybdenum ore at the Climax mine. Rhenium was recovered in the roasting of molybdenite concentrate produced from copper mines of the Kennecott Corp.

AMAX Inc. supplied 64% of the domestic production from its Climax and Henderson mines in Colorado. Output at Climax averaged about 50 million pounds of molybdenum per year for 1978 and 1979; this was below capacity because a lower grade of ore was milled than in previous years. The Henderson mine produced nearly 43 million pounds in 1979 and was expected to reach the designed capacity rate of 50 million pounds per year during 1980. Output at the Questa mine of Molycorp Inc. (a subsidiary of Union Oil Co. of California) in New Mexico decreased to about 5.5 million pounds of molybdenum each year because of problems associated with the open-pit workings and gradual phasing out of surface mining operations.

Duval Corp. (subsidiary of Pennzoil Co.), with three mines in Arizona, and Kennecott Corp., with a total of four mines in Arizona, Nevada, New Mexico, and Utah, were the major producers of byproduct and coproduct molybdenum. The two firms accounted for 24% of domestic output in 1978 and 1979. Duval's Sierrita mine and Kennecott's Bingham mine in Utah were the two copper mines that led in molybdenum output. Other producers of byproduct molybdenum were Anamax Mining Co., ASARCO Inc., Cities Service Co., Cyprus Mines Corp., Inspiration Consolidated Copper Co., and Magma Copper Co. (subsidiary of Newmont Mining Corp.), all of which operated copper mines in Arizona. Union Carbide Corp. recovered small quantities of molybdenum at its Pine Creek tungsten mine in California, as did Kerr-McGee Corp. from the processing of uranium ore in New Mexico.

During 1978, byproduct molybdenum recovery was resumed, after several years' hiatus, at the Silver Bell mine of ASARCO Inc. and the Inspiration mine of Inspiration Consolidated Copper Co.; output from the two copper concentrating plants was small. The Esperanza mine of Duval Corp. and the Pima mine of Cyprus Mines Corp. were closed in late 1977 due to the then prevailing weak copper market. Operations at the two mines, including byproduct molybdenum recovery, were resumed in mid-1979. In 1979, copper ore production and byproduct molybdenum recovery were initiated from the Palo Verde deposit, adjacent to ASARCO's Mission copper mine. The deposit is owned by Eisenhower Mining Co., a partnership of ASARCO and Anamax. Ore is conveyed to ASARCO's Mission mill and Anamax's Twin Buttes mill for production of copper and molybdenum concentrates. Mining and concentrating operations at Kennecott's Nevada Mines Division were suspended in mid-1978 and had not restarted by yearend 1979.

Numerous exploration and development projects were spurred by the prevailing tight supply situation with concurrent high prices and the expectation of future growth in world molybdenum demand. If demand projections are borne out, substantial additional output will be required in the 1980's, much of which is likely to be supplied by new domestic mines. U.S. dominance in world molybdenum production and ore reserves should be further augmented.

Among noteworthy projects, Union Oil Co. of California announced that its subsidiary, Molycorp, would develop the Goat Hill orebody into an underground mine and modernize and expand the milling facility at its Questa property. Construction began in 1979 with capacity ore treatment of 18,000 tons per day projected for the middle of 1984. Initial output from underground reserves was expected in 1983, after which 18 to 20 million pounds of molybdenum would be produced annually. Reserves, estimated at 125 million tons of ore grading 0.29% molybdenite (MoS_2), are sufficient to sustain the operation for at least 20 years. Open-pit mining at Questa, which began in 1965, may be terminated prior to the initiation of underground ore production. The company also planned to construct a roasting plant with an annual capacity of 20

Table 2.—Production, shipments, and stocks of molybdenum products in the United States

(Thousand pounds of contained molybdenum)

	Molybdic oxides[1]		Metal powder		Ammonium molybdate		Sodium molybdate		Other[2]		Total	
	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979
Received from other producers	7,087	7,277	32	7	1,036	1,391	29	17	193	134	8,377	8,826
Gross production during year	103,007	110,259	5,792	6,081	3,516	3,728	1,490	1,542	13,978	14,340	127,783	135,950
Used to make other products listed here	28,203	31,224	1,598	1,135	1,563	1,779	1	1	366	57	31,731	34,196
Net production	74,804	79,035	4,194	4,946	1,953	1,950	1,489	1,541	13,612	14,282	96,052	101,754
Shipments	83,220	84,799	4,252	4,946	3,102	3,487	1,565	1,546	13,782	14,641	105,921	109,419
Producer stocks, Dec. 31	5,275	6,172	300	270	495	381	47	58	1,879	1,621	7,996	8,502

[1] Includes technical and purified molybdic oxide and briquets.

[2] Includes ferromolybdenum, calcium molybdate, phosphomolybdic acid, molybdenum disulfide, molybdic acid, molybdenum metal, pellets, molybdenum pentachloride, and molybdenum hexacarbonyl.

million pounds of molybdenum at its Washington, Pa. conversion facility. An existing 6-million-pound roaster would be retained for extra capacity. The new roaster, which would connect to a sulfuric acid plant for pollution control, was to become operational to coincide with the production of concentrate from the Questa underground mine.

The Anaconda Company planned to construct a surface molybdenum mine in central Nevada north of Tonopah. Annual production was estimated to reach 12 to 15 million pounds of molybdenum in concentrate, with initial output in 1981. Ore reserves at the property were estimated at 150 million tons, and the mine was expected to operate for about 20 years.

In early 1980, Cyprus Mines Corp., which became a subsidiary of Standard Oil Co. of Indiana in 1979, announced its decision to build a surface mine at its Thomson Creek property in Idaho. Output was expected to begin in mid-1983, with capacity production of 15 to 20 million pounds of molybdenum annually to be attained the following year. According to reports, the deposit has ore reserves of about 200 million tons averaging 0.18% MoS_2.

AMAX Inc. carried out extensive exploratory drilling and technical studies on two major deposits: The Mt. Emmons property near Crested Butte, Colo., and the Mt. Tolman property on the Colville Indian Reservation in Washington State. By yearend 1979, the company had estimated reserves at the Mt. Emmons site at 165 million tons of ore grading 0.43% MoS_2, and the Mt. Tolman site at 900 million tons of ore grading 0.10% MoS_2 and 0.09% copper. Feasibility studies were being conducted at Mt. Emmons, and preliminary plans for an underground mine and concentrator/tailings facility were released. The company worked with community and environmental groups to assure that development would proceed in an acceptable manner, as local opposition to mine development was widely reported. In August 1978, AMAX signed a 3-year exploration agreement with the Colville Confederated Tribes, with whom a leasing agreement for the Mt. Tolman property was being negotiated in late 1979. A molybdenum-copper surface mine could be in operation by the mid-1980's at Mt. Tolman if additional studies indicate development is warranted.

U.S. Borax & Chemical Co. announced that the results of drilling conducted through 1979 indicated ore reserves of about 1.3 billion tons at its Quartz Hill deposit in southeastern Alaska. Ore grade was revised to 0.13% MoS_2 at a 0.05% cutoff. The Quartz Hill deposit, possibly the world's largest in terms of reserves, lies within the Tongass National Forest and Misty Fiords National Monument designated by Executive Order in December 1978. Land use and environmental restrictions will have to be resolved before development could proceed. Provisions in an Alaskan Land Act, which was being considered by Congress at yearend 1979, should determine whether mining at Quartz Hill will be feasible. Reportedly, a mine with annual output of 30 million pounds of molybdenum could be constructed by the mid-1980's if the project is undertaken.

Drilling conducted by UV Industries, Inc.,

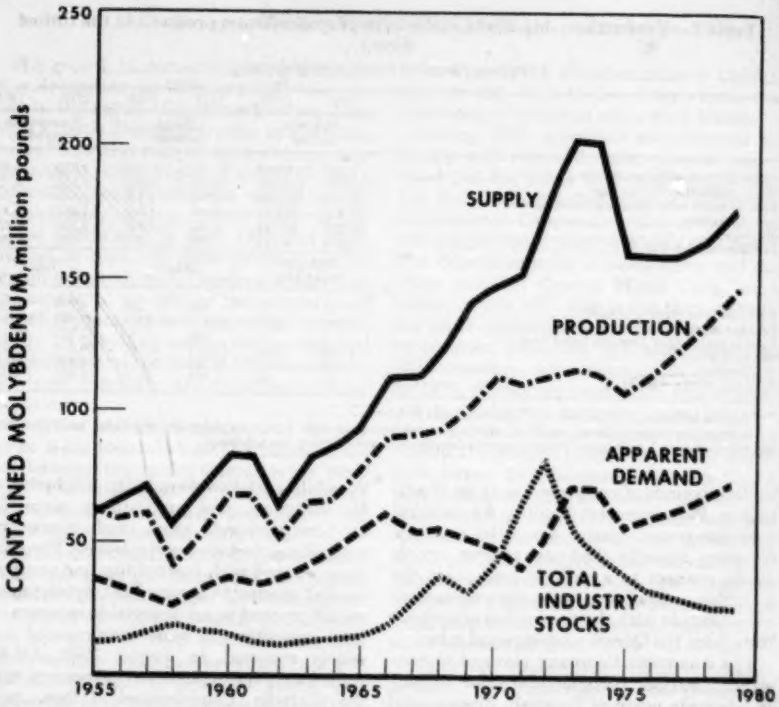

Figure 1.—Apparent demand, supply, production, and total industry stocks of molybdenum in the United States.

encountered molybdenum mineralization at depths of 50 to 700 feet in the Paradise Range area of Nevada. Preliminary results indicated about 28 million tons of mineralized rock grading 0.15% MoS_2. Colby Mines Ltd., of Vancouver, British Columbia, was also reported to have found molybdenum values on claims adjoining the UV Industries' property. Phelps Dodge Corp. and Getty Oil Co. announced that an agreement was reached to explore and evaluate the deep (3,000 to 6,000 feet) molybdenum mineralization found by Phelps Dodge in Beaver County, Utah. Molybdenite grades of 0.29% to 0.38% were encountered in drilling during 1978. The joint venture was expected to require several years of exploration before the feasibility of development could be adequately assessed.

CONSUMPTION AND USES

The quantity of molybdenum in concentrate converted by roasting to produce technical-grade molybdic oxide increased substantially from 1977 to 1979 as both domestic and foreign demand for oxide grew. The oxide was used directly by consumers, particularly steel, cast iron, and superalloy producers, or was converted to other molybdenum raw materials such as ferromolybdenum, high-purity oxide, ammonium and sodium molybdate, and metal powder. Some concentrate was purified to lubrication-grade molybdenum disulfide.

Apparent domestic demand, calculated from mine production, imports minus exports, and change in industry stocks, increased from 61.4 to 73.7 million pounds of molybdenum between 1977 and 1979. Most of the increase in demand was met by the growth in mine output, although higher imports and some emphasis on recycling also contributed to greater supply. Despite the enlarged supply, reduced availability was felt by many consumers.

Table 3.—U.S. consumption of molybdenum, by end use and form

(Thousand pounds of contained molybdenum)

End use	Molybdic oxides	Ferromolybdenum[1]	Ammonium and sodium molybdate	Other molybdenum materials[2]	Total
1978					
Steel:					
Carbon	2,640	226	--	48	2,914
Stainless and heat resisting	6,622	1,164	--	95	7,881
Full alloy	23,326	1,844	--	24	25,194
High-strength low-alloy	1,539	299	--	20	1,858
Tool	3,233	911	--	56	4,200
Cast irons	730	2,951	--	217	3,898
Superalloys	1,821	315	--	1,838	3,974
Alloys (excludes steels and superalloys):					
Welding and alloy hard-facing rods and materials	--	421	--	73	494
Other alloys[3]	148	573	--	220	941
Mill products made from metal powder	--	--	--	4,028	4,028
Chemical and ceramic uses:					
Pigments	558	--	475	7	1,040
Catalysts	2,091	--	540	--	2,631
Other	11	--	17	1,015	1,043
Miscellaneous and unspecified	208	184	49	554	995
Total	42,927	8,888	1,081	8,195	61,091
1979					
Steel:					
Carbon	2,511	194	--	37	2,742
Stainless and heat resisting	7,207	1,285	--	109	8,601
Full alloy	21,454	1,893	--	34	23,381
High-strength low-alloy	1,518	308	--	33	1,859
Tool	2,985	783	--	59	3,827
Cast irons	534	2,737	--	225	3,496
Superalloys	1,956	396	--	2,232	4,584
Alloys (excludes steels and superalloys):					
Welding and alloy hard-facing rods and materials	--	387	--	68	455
Other alloys[3]	229	665	--	138	1,032
Mill products made from metal powder	--	--	--	4,249	4,249
Chemical and ceramic uses:					
Pigments	578	--	541	--	1,119
Catalysts	2,325	--	W	--	2,325
Other	12	--	17	1,109	1,138
Miscellaneous and unspecified	217	212	459	692	1,580
Total	41,526	8,860	1,017	8,985	60,388

W Withheld to avoid disclosing company proprietary data.

[1] Includes calcium molybdate.

[2] Includes purified molybdenum disulfide, molybdenite concentrate added directly to steel, molybdenum metal powder, molybdenum metal, pellets, and other molybdenum materials.

[3] Includes magnetic and nonferrous alloys.

Total reported end-use consumption of molybdenum materials increased 12% from 1977 to 1978, but then decreased slightly in 1979. The leveling of reported consumption, most pronounced during the last quarter of 1979, may have been the result of substitution effects or efforts to conserve molybdenum use due to increased prices and availability problems. Nonetheless, 1978 and 1979 were years of high consumption, approaching the historical peak for consumption reported in 1974.

Molybdenum reported as consumed in the production of steels accounted for about 70% of total consumption in 1978 and 1979. Other metallurgical applications, including molybdenum use in cast irons, superalloys, other alloys, and as a refractory metal, constituted 22% of total consumption. Catalyst, lubricant, pigment, and chemical uses accounted for 8% of reported consumption.

Growth in molybdenum consumption was most pronounced in those products that are generally considered high performance materials: Full alloy and stainless steels, superalloys, and molybdenum mill products. These materials exhibit higher strength at elevated temperatures, greater toughness, and/or superior resistance to wear and corrosion. In contrast, molybdenum consumption in high-strength, low-alloy steels decreased from 1977 to 1979. Molybdenum that formerly had been reported as consumed in electric steels is now being assigned to the full alloy or stainless steel categories.

STOCKS

As has been the case since 1973, world demand exceeded world mine output and industrial inventories of molybdenum were further depleted. Total domestic stocks ranged from 26 to 31 million pounds (contained molybdenum) during most of 1978-79, the lowest levels since 1969. Inventories of molybdenum in concentrate at mines and plants fluctuated between 9 and 13 million pounds, or about a 6-week supply compared with the sum of average monthly roasting and exports of concentrate. Producers' stocks of molybdenum in raw materials ranged from 7 to 10 million pounds, which was equivalent to a 1-month supply when compared with monthly shipments. The very low level of producer stocks served to reduce availability of raw materials to consuming firms. Consumer firms generally held a 2-month supply of molybdenum raw materials (8 to 10 million pounds) when compared with average monthly reported consumption. In some cases, consumer firms with inadequate stocks and increased consumption found it necessary to purchase a portion of their molybdenum supplies at higher prices on the open market.

Table 4.—Industry stocks of molybdenum materials, December 31

(Thousand pounds of contained molybdenum)

Material	1975	1976	1977	1978	1979
Concentrate: Mine and plant	10,680	9,390	9,161	8,980	9,520
Producers:					
Molybdic oxides[1]	17,130	10,003	6,914	5,275	6,172
Metal powder	473	448	327	300	270
Ammonium molybdate	1,347	752	640	495	381
Sodium molybdate	170	71	97	47	58
Other[2]	3,743	1,936	2,163	1,879	1,621
Total	22,863	13,210	10,141	7,996	8,502
Consumers:					
Molybdic oxides[1]	4,036	6,958	5,761	5,893	5,102
Ferromolybdenum[3]	1,416	1,501	1,940	1,864	1,872
Ammonium and sodium molybdate	127	183	338	444	325
Other[4]	1,242	1,235	1,421	1,824	1,761
Total	6,821	9,877	9,460	10,025	9,060
Grand total	40,364	32,477	28,762	27,001	27,082

[1] Includes technical and purified molybdic oxide and briquets.

[2] Includes ferromolybdenum, calcium molybdate, phosphomolybdic acid, molybdenum disulfide, molybdic acid, molybdenum metal, pellets, molybdenum pentachloride, and molybdenum hexacarbonyl.

[3] Includes calcium molybdate.

[4] Includes purified molybdenum disulfide, molybdenite concentrate added directly to steel, molybdenum metal powder, molybdenum metal, pellets, and other molybdenum materials.

PRICES

The continuing tight supply-demand balance and higher operating and development costs resulted in additional price increases during 1978-79. The upward trend in prices, which began in early 1974, has seen the domestic price of the major producers' technical-grade oxide increase from $1.92 at yearend 1973 to $7.50 at yearend 1979 (per pound of contained molybdenum, as are all following price quotes). For the 2-year period 1978-79, Climax oxide, in cans, increased in price from $4.31 to $7.50 (74%) and Climax ferromolybdenum, lump, from $4.99 to $8.40 (68%). Other major producers increased their domestic prices to levels that generally exceeded these of Climax Molybdenum Co. (AMAX Inc.).

In addition to the price increases, a two-tiered price structure, in which prices for exported material were set higher than for domestic sales, characterized the market. In early 1978, export prices were listed from 7% to 10% above domestic prices for oxide and ferromolybdenum. By late 1979, this price differential reached the 20% to 30% range. The stronger foreign market and attempts by producers to limit the domestic price inflation were cited as factors in establishing the two-tiered pricing scheme. Major foreign producers set their prices roughly in the range of export prices set by domestic producers.

The strength of world demand was manifested by dealer price quotations for oxide, which began 1978 at $5.60 to $6.00, about 35% above the Climax price, and at yearend 1978 reached $17 to $18, or 215% above the Climax price. Throughout most of 1979, dealer oxide quotes ranged between $20 and $30, or four to five times the prevailing producer prices for domestic sales. The dealer quotes for oxide fell below $20 near yearend 1979 when supplies became more plentiful and demand was reported to have stabilized somewhat.

Yearend published prices for products, per pound of contained molybdenum, were as follows:

	1978	1979
Climax concentrate (export only)	$5.86	$8.84
Byproduct concentrate	4.50 -5.10	20.00-23.00
Climax oxide/cans	5.56	7.50
Dealer oxide	17.00-18.00	14.25-15.90
K-2 oxide/cans	5.30	9.50
Ferromolybdenum/Climax lump	6.38	8.40
Ferromolybdenum/dealer export	17.00-18.00	16.50-17.75

FOREIGN TRADE

Tariffs.—The Tokyo Round of multilateral trade negotiations was completed in 1979, resulting in new tariff agreements with the developed nations of the world. The agreements placed most nations on a most-favored-nation (MFN) basis with generally lower rates to be phased in over a 7-year period beginning January 1, 1980. Tariff rates for the beginning (January 1, 1980) and ending (January 1, 1987) dates of the staging period are given in table 9. These rates are published in the Tariff Schedules of the United States Annotated (1980).

Exports.—Growth in foreign demand resulted in increased exports of molybdenum in concentrate and oxide from 65.7 million pounds in 1977 to 69.2 million pounds in 1978 and 72.2 million pounds in 1979. These exports represented 51% of domestic mine output and 97% of total exports for 1978 and 1979. The Netherlands, Japan, Belgium-Luxembourg, the Federal Republic of Germany, and the U.S.S.R. were the chief countries of destination. Most of the concentrate exported to the Netherlands was converted to oxide and reshipped, largely to other European countries. The value of concentrate and oxide exports increased strikingly in 1979 because of the higher producer prices for exported material and the escalation of free market prices during the year. With the exception of molybdenum powder, the quantity and value of other exported molybdenum products also increased substantially from 1978 to 1979.

Imports.—Molybdenum in a variety of forms, accounting for 2% to 3% of total U.S. supply, was imported during 1978 and 1979. The total value of imports increased from $9.9 million in 1977 to $66.1 million in 1979, mainly due to higher average prices. As has been the case since 1975, the majority of imports were in the form of concentrate, with Canada supplying about 90% of the total. Canada, Chile, Japan, and numerous West European countries were the principal sources of imports of other molybdenum materials.

Table 5.—Molybdenum reported by producers as shipments for export from the United States

(Thousand pounds of contained molybdenum)

	1978	1979
Molybdenite concentrate	31,183	36,405
Molybdic oxide	33,258	33,920
All other primary products	2,095	1,858

Table 6.—U.S. exports of molybdenum ore and concentrates (including roasted concentrates), by country

(Thousand pounds of contained molybdenum and thousand dollars)

Country	1977		1978		1979	
	Quantity	Value	Quantity	Value	Quantity	Value
Argentina	179	810	56	322	105	1,325
Australia	217	799	230	1,078	190	1,435
Austria	600	2,456	--	--	--	--
Belgium-Luxembourg	7,077	25,560	6,140	27,769	14,834	117,879
Brazil	308	1,272	375	1,858	439	4,667
Canada	524	1,703	1,353	6,128	600	4,798
Chile	--	--	32	206	480	3,691
France	583	2,039	485	2,281	([1])	7
Germany, Federal Republic of	5,598	18,309	6,136	26,555	6,733	87,212
India	529	1,944	165	694	142	1,179
Italy	617	2,724	8	29	([1])	5
Japan	10,425	41,391	10,520	51,305	12,369	111,509
Korea, Republic of	--	--	14	72	--	--
Mexico	635	1,888	735	3,333	865	10,231
Netherlands	32,578	123,421	33,938	162,939	27,938	226,700
New Zealand	5	34	3	21	4	47
Philippines	4	17	14	46	11	66
South Africa, Republic of	188	620	262	996	304	2,891
Spain	([1])	1	--	--	44	634
Sweden	2,282	7,458	2,621	10,740	2,049	23,207
Switzerland	--	--	4	35	317	4,019
Taiwan	38	259	1	4	2	14
United Kingdom	895	3,289	1,217	5,813	1,898	16,187
U.S.S.R	2,388	9,777	4,840	26,065	3,463	41,098
Other	1	6	1	5	5	81
Total	65,666	245,777	69,150	328,294	72,242	658,882

[1] Less than 1/2 unit.

Table 7.—U.S. exports of molybdenum products

(Thousand pounds, gross weight, and thousand dollars)

Product and country	1978		1979	
	Quantity	Value	Quantity	Value
Ferromolybdenum:[1]				
Australia	264	988	385	2,558
Bolivia	--	--	10	78
Canada	122	420	339	1,400
Colombia	3	10	17	89
India	145	575	47	222
Japan	425	2,090	628	4,184
Korea, Republic of	44	301	2	7
Mexico	1	7	81	149
Netherlands	163	966	141	893
Peru	4	21	7	71
South Africa, Republic of	88	353	44	231
Sweden	63	218	--	--
United Kingdom	135	717	6	26
Other	9	55	24	127
Total	1,466	6,721	1,681	10,080
Metal and alloys in crude form and scrap:				
Belgium	9	94	39	414
Brazil	2	17	3	89
Canada	16	76	53	250
France	1	5	14	289
Germany, Federal Republic of	80	419	489	3,788
India	5	38	4	97
Japan	113	660	44	575
Mexico	33	133	72	827
Netherlands	--	--	140	1,615
Sweden	--	--	167	874
Taiwan	61	5	1	11
United Kingdom	7	46	110	1,104
Other	62	56	6	64
Total	389	1,549	1,142	9,997

See footnotes at end of table.

Table 7.—U.S. exports of molybdenum products —Continued

(Thousand pounds, gross weight, and thousand dollars)

Product and country	1978		1979	
	Quantity	Value	Quantity	Value
Wire:				
Argentina	4	64	5	96
Australia	13	15	15	199
Austria	2	29	11	151
Belgium-Luxembourg	--	--	8	170
Brazil	22	495	46	918
Canada	55	589	60	872
Finland	--	--	4	115
France	59	833	43	740
Germany, Federal Republic of	116	1,616	146	2,371
India	2	46	8	170
Italy	49	651	48	784
Japan	79	99	116	1,574
Mexico	12	282	13	439
Netherlands	--	--	18	467
South Africa, Republic of	45	674	8	142
Singapore	2	406	21	447
Spain	9	121	21	328
Sweden	3	67	1	20
Switzerland	--	--	7	112
United Kingdom	13	184	32	470
Other	10	432	33	437
Total	495	6,603	664	11,022
Powder:				
Algeria	17	150	--	--
Argentina	--	--	8	103
Canada	2	17	13	155
France	4	35	6	85
Germany, Federal Republic of	87	472	9	158
Israel	41	89	1	14
Italy	6	73	2	32
Japan	109	506	113	790
Mexico	70	303	10	168
Netherlands	37	284	80	778
Taiwan	5	47	18	160
United Kingdom	32	230	17	309
U.S.S.R	191	553	--	--
Other	21	134	24	230
Total	622	2,893	296	2,982
Semifabricated forms, n.e.c.:				
Australia	8	120	4	77
Brazil	12	85	8	161
Canada	29	439	16	360
France	13	504	34	999
Germany, Federal Republic of	37	596	31	845
Japan	18	409	13	306
Mexico	3	44	27	126
Netherlands	17	540	66	1,287
Philippines	4	5	9	86
Singapore	(2)	17	24	52
South Africa, Republic of	(2)	2	19	239
United Kingdom	50	724	19	640
Other	57	330	19	370
Total	248	3,815	289	5,548
Molybdenum compounds:				
Argentina	1	7	161	2,717
Australia	11	32	254	2,373
Belgium-Luxembourg	(2)	2	160	1,879
Brazil	2	9	142	2,478
Canada	610	1,215	439	2,676
Chile	--	--	26	275
France	43	184	--	--
Germany, Federal Republic of	498	1,253	2,004	23,402
India	46	137	51	850
Japan	925	3,781	3,908	38,287
Mexico	344	1,109	111	1,319
Netherlands	176	980	2,142	24,656
South Africa, Republic of	233	1,428	55	966
Spain	5	5	50	654
Sweden	31	64	366	4,044
Switzerland	--	--	39	466
Taiwan	21	133	51	400
United Kingdom	8	35	312	2,530
Other	50	263	21	191
Total	3,004	10,587	10,293	110,163

[1] Ferromolybdenum contains about 60% to 65% molybdenum.
[2] Less than 1/2 unit.

Table 8.—U.S. imports for consumption of molybdenum products

(Thousand pounds and thousand dollars)

TSUS No.	Material	1978			1979		
		Gross weight	Contained molybdenum	Value	Gross weight	Contained molybdenum	Value
601.33	Ore and concentrate	6,003	2,705	15,853	5,309	2,329	26,211
603.40	Material in chief value molybdenum	7,997	1,541	6,760	1,171	690	12,060
606.31[1]	Ferromolybdenum	364	261	1,499	62	47	636
628.70	Waste and scrap	243	NA	1,253	336	NA	5,596
628.72	Unwrought	NA	181	1,113	NA	85	1,566
628.74	Wrought	119	NA	1,931	104	NA	2,306
417.28	Ammonium molybdate	1	1	5	1,068	613	13,152
419.60	Molybdenum compounds	886	512	2,932	332	196	3,218
421.10	Sodium molybdate	5	4	26	98	45	287
423.88	Mixtures of inorganic compounds, chief value molybdenum	107	62	416	5	2	11
473.18	Molybdenum orange	671	NA	681	823	NA	1,065
	Total	16,396	5,267	32,469	9,308	4,007	66,108

NA Not available.
[1] TSUS No. 607.40 prior to January 1, 1980.

Table 9.—U.S. import duties on molybdenum articles

TSUS No.	Article	Most Favored Nation (MFN)		Non-MFN
		January 1, 1980	January 1, 1987	January 1, 1980
601.33	Ore and concentrate	11.6 cents per pound	9 cents per pound	35 cents per pound
603.40	Material in chief value molybdenum	9.5 cents per pound plus 2.9% ad valorem	6 cents per pound plus 1.9% ad valorem	50 cents per pound plus 15% ad valorem
606.31	Ferromolybdenum	10 cents per pound plus 3% ad valorem	4.5% ad valorem	31.5% ad valorem
	Molybdenum:			
628.70	Waste and scrap	9.9% ad valorem[1]	6% ad valorem	50% ad valorem[1]
628.72	Unwrought	9.5 cents per pound plus 2.9% ad valorem	6.3 cents per pound plus 1.9% ad valorem	50 cents per pound plus 15% ad valorem
628.74	Wrought	11.8% ad valorem	6.6% ad valorem	60% ad valorem
	Molybdenum chemicals:			
417.28	Ammonium molybdate	6% ad valorem	4.3% ad valorem	29% ad valorem
418.26	Calcium molybdate	4.8% ad valorem	4.7% ad valorem	24.5% ad valorem
419.60	Molybdenum compounds	4% ad valorem	3.2% ad valorem	20.5% ad valorem
420.22	Potassium molybdate	3.7% ad valorem	3% ad valorem	23% ad valorem
421.10	Sodium molybdate	4.9% ad valorem	3.7% ad valorem	25.5% ad valorem
423.88	Mixtures of inorganic compounds, chief value molybdenum	3.5% ad valorem	2.8% ad valorem	18% ad valorem
473.18	Molybdenum orange	5% ad valorem	5% ad valorem	25% ad valorem

[1]Duty on waste and scrap temporarily suspended.

WORLD REVIEW

World mine production of molybdenum increased from 210 million pounds in 1977 to an average of 224 million pounds for 1978 and 1979. Estimated output in 1979 increased less than expected over that of 1978 primarily because of labor problems which reduced Canadian production about 8 to 10 million pounds below capacity. The United States, Canada, Chile, and the U.S.S.R. (production estimated) continued to supply almost all of the world output. Indirect evidence indicated that world demand exceeded production during 1978 and 1979 and that demand was particularly strong in West European countries.

Argentina.—Cia. Minera Aguilar, S.A., a subsidiary of St. Joe Minerals Corp., was reportedly very close to deciding on the investment of nearly $1 billion to develop the El Pachon copper deposit in San Juan Province. Extensive drilling has indicated about 873 million tons of ore averaging 0.6% copper and 0.016% molybdenum. Milling plans are likely to include byproduct molybdenum recovery circuits, but it would take at least 5 years for the project to reach the production stage.

Canada.—Mine production was well below capacity, especially in 1979, due to labor disruptions at major mines. Most adverse

Table 10.—Molybdenum: World mine production, by country

(Thousand pounds contained molybdenum)

Country[1]	1976	1977	1978[p]	1979[e]
Australia[r]	(2)	(2)	--	--
Bulgaria[e]	300	330	330	330
Canada (shipments)	32,229	36,526	31,015	24,700
Chile	24,028	24,114	29,092	28,000
China, Mainland[e]	3,300	3,300	4,400	4,400
Japan	[r]485	401	278	300
Korea, Republic of	264	222	483	800
Mexico	35	2	24	50
Peru	[r]999	1,021	1,607	1,800
Philippines	--	--	50	250
U.S.S.R.[e]	20,600	21,400	21,800	22,500
United States	113,233	122,408	131,843	143,967
Total	[r]195,473	209,724	220,922	227,097

[e]Estimate. [p]Preliminary. [r]Revised.

[1]In addition to the countries listed, North Korea, Romania, Turkey, and Yugoslavia are believed to produce molybdenum, but output is not reported quantitatively, and available general information is inadequate to make reliable estimates of output levels.

[2]Revised to zero.

was the strike that began on February 15, 1979, at Placer Development Ltd.'s Endako mine and was not terminated until a new labor contract was approved on November 1. The cutback in normal operations at this mine, which supplied nearly 45% of Canadian output in 1978, exacerbated the constricted world availability of molybdenum in 1979. Protracted strikes also occurred at the Gibraltar mine (71.9% owned by Placer Development Ltd.) from May 1978 to February 1979 and at Gaspe Mines of Noranda Mines Ltd. from October 1978 to June 1979. Both are copper mines at which byproduct molybdenum is recovered. A 1-month strike at Noranda's Brenda mine, a copper-molybdenum mine and Canada's second leading molybdenum producer, was resolved in mid-October 1979. Overall output was also affected by lower ore grades milled at Endako, Brenda, and Noranda's Boss Mountain molybdenum mine.

Placer Development Ltd. announced that annual roasting capacity at the Endako property was to be increased from 17 million to about 24 million pounds of molybdic oxide. Construction of a facility to produce 1 million pounds of purified molybdenum disulfide per year was also planned. Both projects were delayed as a result of the strike during 1979. Noranda was evaluating the feasibility of mining lower grade surface ore adjoining underground reserves presently being mined at its Boss Mountain property.

During the second half of 1978 molybdenum recovery circuits were started up at the concentrating plant of Bethlehem Copper Corp.'s copper property in the Highland Valley region of British Columbia. While production was mainly from the Iona pit, other mineralized zones on the property were being explored for copper and molybdenum. Over 400,000 pounds of molybdenum in concentrate was recovered in 1978; annual output of about 1 million pounds of molybdenum was anticipated.

Lornex Mining Corp. Ltd. (68.1% owned by Rio Algom Ltd.) announced a $160 million program to increase mining and milling capacity at its Lornex copper-molybdenum mine in British Columbia. The project is due to be completed in mid-1981 and will expand ore throughput from the current 48,000 tons to between 74,000 tons and 80,000 tons per day. Production of molybdenum in concentrate should increase from 4 million to about 6.5 million pounds per day with the added ore treatment capacity.

AMAX Inc. planned to resume mining and milling at the Kitsault (Lime Creek) property located in the Alice Arms area of British Columbia. The property was acquired by AMAX in 1973 after operations were terminated in 1972 under different ownership. Ore processing capacity is to be expanded to 12,000 tons per day with 9 to 10 million pounds of molybdenum production per year. Initial output was expected in the latter half of 1981. Proven and possible ore reserves were reported at 105 million tons averaging 0.192% MoS_2.

Early in 1979, Teck Corp. Ltd. announced that it would develop a mine and 25,000-ton-per-day concentrating plant at the Highmont copper-molybdenum deposit in British Columbia's Highland Valley. Teck holds 50.29% interest in Highmont Mining Corp., owner of the property. The mine was to come onstream in late 1980 or early 1981, after which molybdenum output would be between 9 and 6.5 million pounds during the first 2 years of operation, then decrease to 4.5 million pounds per year for the remainder of the 10- to 13-year life of the mine. Teck also purchased from Hecla Mining Co. a 70% interest in the Schaft Creek copper-molybdenum-gold deposit in British Columbia. Teck was to conduct further exploration of the property, which contains an estimated 350 million tons of ore grading 0.39% copper, 0.036% molybdenum, and significant gold values.

In Charlotte County, New Brunswick, a tin-molybdenum-tungsten-bismuth prospect owned by Brunswick Tin Mines Ltd. (89% controlled by Sullivan Mining Group Ltd.) was committed for development in a joint venture with Billiton Exploration Canada Ltd. The mine is scheduled for completion by late 1981 with output planned at about 3 million pounds of tungsten in concentrate and 1.3 million pounds of molybenite concentrate per year. Dumagami Mines Ltd. was studying the feasibility of recovering molybdenite at a property that includes the former Preissac Molybdenum Mines holdings in the Cadillac district of northwestern Quebec. With the help of Noranda, a major shareholder of Dumagami, the firm was planning to construct a 1,000-ton-per-day ore concentrator by yearend 1980.

Numerous Canadian molybdenum properties were being drilled and evaluated, particularly in British Columbia. At the Trout Lake prospect, southeast of Revelstoke, drilling conducted by Newmont Mining Corp. and Esso Minerals Canada (a division of Imperial Oil Ltd.) encountered significant mineralization at depth where previous shallow drilling had produced indifferent results. Adanac Mining and Exploration Ltd. sold an option in 1978 to Placer Development Ltd. for 70% interest in the Ruby Creek molybdenum prospect near Atlin. According to terms of the option, Placer was to complete certain work on the property, which has been estimated to contain about 105 million tons of ore grading 0.16% MoS_2. Amax Minerals Exploration Ltd., a unit of AMAX Inc., was evaluating a tungsten-molybdenum property near the Yukon-British Columbia border on an option from the owner, Logtung Resources Ltd. Drilling has indicated potential ore reserves of 180 million tons averaging 0.13% tungsten and 0.052% molybdenum.

Chile.—Chilean mine output of molybdenum increased during 1978 and 1979 because of improved recovery from copper mines operated by the State-owned Corporación National del Cobre de Chile (CODELCO). The Chuquicamata and El Teniente copper mines accounted for about 90% of total production. A new molybdenum plant was started up at the concentrator of CODELCO's El Salvador mine during 1978. At the Chuquicamata mill, a roasting facility was under construction and was expected to be operational in 1980.

The Anaconda Company purchased the Los Pelambres copper-molybdenum deposit from private Chilean owners for $20 million. Previous exploratory work has established over 400 million tons of ore grading 0.78% copper and 0.03% molybdenum on the property. Anaconda is to spend several years on further evaluation, after which construction of a mine and mill complex may proceed at an estimated cost of $1.5 billion. Several major international mining and petroleum firms were participating in studies of other copper-molybdenum properties that have future mining potential.

Iran.—The political and social upheaval in Iran of late 1978 and 1979 delayed indefinitely the startup of mining at the Sar Cheshmah copper deposit. Mining, concentrating, and smelting facilities had been nearly completed when activity was halted. Resumption of work on the site will be dependent on development priorities of the new regime and the availability of trained manpower. Up to 4 million pounds of byproduct molybdenum was expected to be produced annually at the Sar Cheshmah concentrating plant.

Mexico.—After nearly 10 years of work and numerous delays, operations at the large La Caridad copper mine were inaugurated in June 1979. Located in northern Sonora State and operated by Cia. Mexicana de Cobre, S.A., a company held by Mexican State agencies and Mexican and foreign investors, the deposit contains estimated reserves of 750 million tons grading 0.67% copper and 0.02% molybdenum. Capacity ore production will eventually reach 90,000 tons per day when expanded. Recovery of byproduct molybdenum is anticipated, possibly by 1981, with output to increase as deeper, higher grade portions of the orebody are mined. Annual output of about 2 million pounds of molybdenum is expected after installation of molybdenum recovery circuits.

Minera Frisco S.A. was developing the Cumobabi deposit, in Sonora State, for production in mid-1980. Reportedly, mining will begin on higher grade ore from underground breccia pipes and later move to open-pit extraction of lower grade prophyry ore surrounding the pipes. Ore processing capacity will start at 600 tons per day and expand to 1,200 tons per day. A roasting plant was being installed with initial output in the range of 1.5 to 3.5 million pounds of molybdenum per year.

A joint exploration program undertaken by AMAX Inc. and Minera Mexicana Peñoles S.A. has delineated mineralization in excess of 100 million tons in the Opedepe (Meztli) region of Sonora. Average grade is estimated at 0.18% molybdenite.

Peru.—The Government of Peru approved plans for construction of a byproduct molybdenum recovery plant at the Botiflaca concentrator of the Cuajone copper mine, operated by Southern Peru Copper Corp. (SPCC). Although originally scheduled for completion in 1979, construction was delayed and, according to reports, the plant will not be operational until 1981. At capacity operation, output has been variously stated at 2 to 4 million pounds of molybdenum in concentrate per year. Currently almost all Peruvian molybdenum production is recovered from the copper ore of SPCC's Toquepala mine.

Philippines.—Atlas Consolidated Mining & Development Corp. initiated molybdenum recovery at its Biga copper concentrator during the fourth quarter of 1978. About 54,000 pounds of molybdenum in byproduct concentrate was produced in 1978; output increased substantially in 1979 during the first full year of operation. In past years, sporadic output of molybdenum has been recorded in the Philippines as a byproduct from the Sipalay copper mine of Marinduque Mining & Industrial Corp. Molybdenum recovery at Sipalay was increased during 1979. Black Mountain, Inc., was considering the recovery of molybdenum at its Kennon copper mine on Luzon Island.

TECHNOLOGY

After several years of work developing an electrooxidation process to extract molybdenum and rhenium from molybdenite concentrates, Bureau of Mines researchers constructed and operated a prototype cell for the process.[2] Design factors were identified to minimize current leakage and improve efficiency of the bipolar prototype cell. The cell was tested on offgrade molybdenite concentrates produced at the Nevada Mines Division of Kennecott Corp. Extraction of 84% to 97% of the molybdenum and rhenium was achieved; recovery was adversely affected if the copper content, as chalcocite, exceeded 7% in the concentrate.

Molybdenum metal and alloys are a potential substitute for superalloys containing nickel, cobalt, and chromium, but require protection from high-temperature oxidation. The performance of several complex oxides of the spinel and perovskite structure was analyzed as oxidation-barrier coatings on molybdenum metal.[3] Examination of oxygen and molybdenum diffusion rates, vaporization rate, erosion resistance, reactivity, ease of application, and other properties was undertaken to evaluate coating performance. Two spinels, $MgCr_2O_4$ and $MgAl_2O_4$, exhibited the most acceptable performance in comparison with currently available $MoSi_2$ coatings.

Significant industrial research was concerned with the development of metallurgical products that benefit from molybdenum's alloying properties. High-strength, low-alloy dual-phase steels that exhibit good ductility and formability at high strength were investigated.[4] Small additions of molybdenum promote the desired dual-phase grain structure. These steels offer the advantage of acceptable strength with reduced steel thickness; weight savings gained by their usage in transportation vehicles, especially automobiles, can potentially reduce fuel consumption. A grade of these dual-phase steels was produced that can be manufactured directly as a coiled hot-strip product, thus eliminating the need for heat treatment.[5]

Other metallurgical products containing molybdenum that were under development include chromium-molybdenum steels for high-strength, as-rolled rails,[6] high-chromium-molybdenum white irons for thick-section castings,[7] a low alloy steel with high strength and resistance to sulfide stress cracking suitable for use in oil and gas drilling equipment,[8] and carburizing steels with very high hardenability for use in drilling deep, large-diameter oil wells.[9]

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[1] Physical scientist, Section of Ferrous Metals.

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Nickel

By Norman A. Matthews[1]

The nickel market improved progressively during 1978 and 1979. Domestic consumption reached near-record levels in 1979 as stainless steel, superalloy, and other high-nickel-alloy producers operated at capacity levels. With respect to the United States, recovery of high demand levels in Western Europe and Japan followed about 6 months and 1 year later, respectively, so that world consumption of primary nickel in 1979 attained a record level, estimated at 829,000 tons.

Major producers operated at 55% to 60% of capacity in 1978 to reduce excessive inventories and arrest the progressive price deterioration that began in 1977. Continued curtailment of production during 1979, with operations at perhaps 70% capacity, improved demand, and a major work stoppage for 9 months led to below-normal producer inventories, the reestablishment of firm producer prices, and several price increases during the year. Most of the laterite operations were unprofitable at the reduced volumes and depressed prices of 1978, but they began to show a profit in the second half of 1979 after prices increased over 50%.

The domestic pattern of usage remained substantially unchanged, with 45% consumed in stainless and alloy steels; 35%, in nonferrous nickel- and copper-base alloys; and 15%, in electroplating. During the 2-year period, the percentage of nickel consumed as Class I nickel forms (cathode, briquets, and pellets) increased, while the percentage consumed as ferronickel and nickel oxide declined, reversing the trend of recent years.

Cathode nickel prices, although generally not listed, approximated $2.08 per pound through mid-1978, gradually declining to a range of $1.93 to $2.00 by November. Most sales were at these or lower prices as producers and metal merchants maneuvered to sustain sales in the highly competitive market. The domestic ferronickel price stabilized at $1.38 per pound nickel by midyear and declined further to $1.83 at yearend. With the reestablishment of producer list prices in February 1979, five price increases followed, which increased cathode and other pure nickel prices to $3.00 per pound by June, and $3.20 to 3.25 per pound in December.

Table 1.—Salient nickel statistics

(Short tons)

	1975	1976	1977	1978	1979
United States:					
Mine production[1]	16,987	16,469	14,347	13,509	15,065
Plant production:					
Domestic ores	14,343	13,869	12,897	11,298	11,691
Imported materials	7,978	20,070	[r]25,000	26,000	32,500
Secondary[2]	17,880	13,273	12,449	12,304	13,201
Exports (gross weight)	30,121	47,166	39,412	36,293	50,810
Imports for consumption	160,507	188,147	[r]194,770	240,032	183,742
Consumption (primary)	146,495	162,927	155,260	180,723	196,293
Stocks, Dec. 31: Consumer	35,485	31,690	[r]18,581	20,443	19,518
Price, cents per pound	201-220	220	241-208	210-193	193-320
World: Mine production	890,532	883,941	[r]904,455	731,371	776,516

[r] Revised.

[1] Mine shipments.

[2] Nonferrous scrap only; does not include nickel from stainless or alloy steel scrap.

World production capacity expected by the end of 1980 appears adequate for projected requirements through 1985; additional facilities under construction and planned are probably sufficient to provide the incremental capacity required through 1990.

DOMESTIC PRODUCTION

The domestic nickel mine of Hanna Mining Co., Riddle, Oreg., shipped 13,509 short tons of nickel in laterite ore, in 1978. Nickel recovered at the smelter as ferronickel, and byproduct nickel salts and metal produced at copper and other metal refineries totaled 11,298 tons. The mine and smelter closed for extended periods during the year to balance production with inventories. Refined volume was similar in 1979 with higher tonnages of lower grade ore providing equivalent nickel production. The Port Nickel, La., refinery of AMAX Nickel Inc. was operated at about 75% of capacity on imported matte during 1978 and produced 26,000 tons of refined nickel along with copper, cobalt, and ammonium sulfate. Matte for the refinery came from Bamangwato Concessions Ltd. in Botswana, Rustenburg Platinum Mines Ltd. in the Republic of South Africa, and Société Métallurgique le Nickel (SLN) in New Caledonia. First shipments of high-nickel matte from the Agnew mine operation in western Australia were received early in 1979; receipts from this source totaled 2,592 tons of nickel in 1979. The refinery produced an estimated 32,500 tons of nickel in 1979, although output was curtailed by a work stoppage of hourly workers during the last 4 months.

AMAX Exloration, Inc. continued evaluation of the Duluth gabbro sulfide deposit in northeast Minnesota by excavating 3,420 feet of drifts into the deposit and removing 60,000 tons of bulk samples for metallurgical tests and for environmental studies. In cooperation with State agencies, comprehensive studies of surface and ground water hydrology, aquatic and terrestrial biology, and vegetation were started. In 1979, a multi-agency task force of the State of Minnesota reported the results of a 4-year study on the implications of copper-nickel mining and concluded that mining was feasible with the application of modern technology to protect the environment.[5]

There was increased activity in developing the laterite deposits of northern California and southwestern Oregon. California Nickel Corp. was engaged in development drilling at Eight Dollar Mountain and other sites in Josephine and Curry Counties in Oregon and Del Norte County in California. The company acquired control of claims reportedly containing over 30 million tons of ore. The Oregon Department of Geology and Mineral Resources published a paper covering the statewide laterite resources of 24 deposits in Curry and Josephine Counties and in the Illinois Valley and Red Flat area.[6]

International Metals Reclamation Co. Inc. (INMETCO), a subsidiary of Inco United States Inc., began production of alloy pigs from stainless steel plant particulate wastes at a new plant in Ellwood City, Pa. in December 1978. The plant feed is a pelletized blend of flue dust, mill scale, grindings, and reductant, which is smelted and refined in electric furnaces to produce a product of guaranteed analysis approximating 18% chromium and 8% nickel. Plant capacity is 40,000 tons annually of particulate material, to produce 25,000 tons of alloy pigs. Near-capacity operations were achieved in the last quarter of 1979.

CONSUMPTION AND USES

Demand for nickel increased progressively in 1978 and 1979. Total demand, including secondary nickel, was 224,905 tons and 253,697 tons in 1978 and 1979, respectively. The latter figure was second only to the record year 1974. Most of the increased demand was in stainless steels and superalloys. Producers of these end products operated at near-capacity during the last 6 months of 1978 and throughout 1979. Nickel consumption for electroplating and for the production of high-nickel heat- and corrosion-resistant alloys also increased substantially. Consumer stocks increased from the low levels of 1977 but remained modest, equivalent to 4 to 6 weeks' consumption.

Pure unwrought nickel increased its share of the total primary nickel market, reversing the trend of recent years. Pure unwrought nickel constituted 68% of the total; ferronickel, 20%; and nickel oxide sinter, 11%. The pure forms were utilized principally in the production of nickel wrought products, high-nickel heat and corrosion-resistant alloys, copper-base al-

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loys, and in electroplating, whereas ferronickel and the oxide sinter were used largely in the production of stainless and alloy steels.

Although primary nickel consumption increased during the 2-year interval, the pattern of consumption by type of product remained similar, as follows: Stainless and heat-resisting steels, 35%; high-nickel heat- and corrosion-resistant alloys, 23%; electroplating, 16%; alloy steels, 10%; and superalloys, 8%.

Table 2.—Nickel recovered from nonferrous scrap processed in the United States, by kind of scrap and form of recovery

(Short tons)

Kind of scrap	1977	1978	1979	Form of recovery	1977[r]	1978	1979
New scrap:							
Nickel-base	1,532	2,162	2,490	As metal	574	685	633
Copper-base	3,159	2,270	3,130	In nickel-base alloys	2,367	2,615	2,606
Aluminum-base	1,554	1,670	1,903	In copper-base alloys	6,833	5,786	4,661
Total	6,245	6,102	7,523	In aluminum-base alloys	1,703	2,104	2,285
Old scrap:				In ferrous and high-temperature alloys[1]	79	239	2,053
Nickel-base	5,628	5,680	5,016	In chemical compounds	893	875	963
Copper-base	445	355	484				
Aluminum-base	131	167	178	Total	12,449	12,304	13,201
Total	6,204	6,202	5,678				
Grand total	12,449	12,304	13,201				

[r] Revised.

[1] Includes only nonferrous scrap added to ferrous high-temperature alloys.

Table 3.—Stocks and consumption of new and old nickel scrap in the United States in 1978 and 1979

(Gross weight, short tons)

Class of consumer and type of scrap	1978						1979					
	Stocks, beginning of year	Receipts	Consumption			Stocks, end of year	Stocks, beginning of year	Receipts	Consumption			Stocks, end of year
			New	Old	Total				New	Old	Total	
Smelters and refiners:												
Nickel and nickel alloys	134	6,572	2,100	4,497	6,597	109	109	6,619	2,129	4,525	6,654	74
Nickel-copper metal	334	1,010	585	526	1,111	233	233	1,040	658	388	1,046	227
Nickel-silver[1]	728	2,544	380	2,421	2,801	471	471	3,942	551	3,218	3,769	644
Cupronickel[1]	109	34	--	129	129	14	14	59	--	50	50	23
Nickel residues	W	W	W	W	W	W	W	W	W	W	W	W
Total	468	7,582	2,685	5,023	7,708	342	342	7,659	2,787	4,913	7,700	301
Foundries and other manufacturers:												
Nickel and nickel alloys	310	1,985	1,342	805	2,147	148	148	1,773	1,429	355	1,784	137
Nickel copper metal	39	215	--	220	220	34	34	--	--	--	--	34
Nickel-silver[1]	1,004	10,401	9,882	6	9,888	1,517	1,517	10,266	10,327	35	10,362	1,421
Cupronickel[1]	1,659	7,893	8,007	1	8,008	1,544	1,544	18,270	17,085	94	17,179	2,635
Nickel residues	118	563	394	162	556	125	125	947	700	222	922	150
Total	467	2,763	1,736	1,187	2,923	307	307	2,720	2,129	577	2,706	321
Grand total:												
Nickel and nickel alloys	444	8,557	3,442	5,302	8,744	257	257	8,392	3,558	4,880	8,438	211
Nickel-copper metal	373	1,225	585	746	1,331	267	267	1,040	658	388	1,046	261
Nickel-cilver[1]	1,732	12,945	10,262	2,427	12,689	1,988	1,988	14,208	10,878	3,253	14,131	2,065
Cupronickel[1]	1,768	7,927	8,007	130	8,137	1,558	1,558	18,329	17,085	144	17,229	2,658
Nickel residues	118	563	394	162	556	125	125	947	700	222	922	150
Total	935	10,345	4,421	6,210	10,631	649	649	10,379	4,916	5,490	10,406	622

W Withheld to avoid disclosing company proprietary data; included in "Nickel and nickel alloys."

[1] Excluded from totals because it is copper-base scrap, although containing considerable nickel.

Table 4.—Nickel (exclusive of scrap) consumed in the United States, by form

(Short tons, contained nickel)

Form	1975	1976	1977	1978	1979
Metal	99,693	104,374	96,058	122,972	135,987
Ferronickel	25,325	31,210	31,784	33,272	39,977
Oxide powder and oxide sinter	16,630	22,198	22,446	19,817	14,189
Salts[1]	1,751	2,437	2,395	2,026	3,944
Other	3,096	2,708	2,577	2,636	2,196
Total	146,495	162,927	155,260	180,723	196,293

[1] Metallic nickel salts consumed by plating industry are estimated.

Table 5.—U.S. consumption of nickel (exclusive of scrap), by use and form

(Short tons, contained nickel)

Year and use	Commercially pure unwrought nickel	Ferronickel	Nickel oxide	Nickel sulfate and other nickel salts	Other forms	Total
1978						
Steel:						
Stainless and heat-resisting	25,663	25,676	9,104	--	30	60,473
Alloys (excludes stainless)	4,372	4,436	8,017	--	342	17,167
Superalloys	14,793	591	89	--	212	15,685
Nickel-copper and copper-nickel alloys	6,723	9	115	--	172	7,019
Permanent magnet alloys	735	79	3	--	1	818
Other nickel and nickel alloys	36,198	2,194	962	36	243	39,633
Cast irons	1,957	237	931	1	1,153	4,279
Electroplating (sales to platers)[1]	25,742	--	18	1,553	6	27,319
Chemicals and chemical uses	1,236	--	457	172	21	1,886
Other uses[2]	5,553	50	121	264	456	6,444
Total reported by companies canvassed and estimated	122,972	33,272	19,817	2,026	2,636	180,723
1979						
Steel:						
Stainless and heat-resisting	33,529	31,710	4,325	--	62	69,626
Alloys (excludes stainless)	7,910	4,680	7,543	--	39	20,172
Superalloys	16,359	743	131	7	319	17,559
Nickel-copper and copper-nickel alloys	8,330	--	99	--	32	8,461
Permanent magnet alloys	659	23	11	--	--	693
Other nickel and nickel alloys	37,460	2,557	844	24	206	41,091
Cast irons	2,488	263	641	23	1,286	4,701
Electroplating (sales to platers)[1]	24,929	--	58	3,554	5	28,546
Chemicals and chemical uses	691	--	301	69	104	1,165
Other uses[2]	3,632	1	236	267	143	4,279
Total reported by companies canvassed and estimated	135,987	39,977	14,189	3,944	2,196	196,293

[1] Based on monthly estimated sales to platers.

[2] Includes batteries, ceramics, and other alloys containing nickel.

Table 6.—Nickel (exclusive of scrap) in consumer stocks in the United States, by form

(Short tons, contained nickel)

Form	1977	1978	1979
Metal	9,710	10,657	14,716
Ferronickel	3,944	5,575	2,467
Oxide powder and oxide sinter	4,007	3,437	1,314
Salts	397	392	427
Other	523	382	594
Total	18,581	20,443	19,518

Table 7.—Consumption, stocks, receipts, shipments, and/or sales of secondary nickel in 1978 and 1979, by use

(Short tons, contained nickel)

Use	Receipts		Consumption		Shipments or Sales		Stocks, end of year	
	1978	1979	1978	1979	1978	1979	1978	1979
Steel (stainless and heat-resisting and alloy)	32,687	41,244	28,200	40,040	4,254	4,080	7,540	7,020
Nonferrous alloys (super, nickel-copper and copper-nickel, permanent magnet, and other nickel)	3,291	3,896	3,295	3,841	18	5	458	518
Foundry (cast irons)	369	335	380	316	--	--	14	5
Chemicals (catalysts, ceramics, plating salts, and other chemical uses)	4	6	3	6	--	--	3	5
Total reported by companies canvassed and estimated	36,351	45,481	31,878	44,203	4,272	3,085	8,015	7,598

PRICES

Prices declined generally during 1978, but the lack of published prices made precise analysis difficult. Cathode nickel prices quoted to major consumers (per pound nickel contained) were $2.08 through August with a premium of $0.03 to $0.05 for small-cut cathode for plating. In general, pure briquets and pellets sold at competitive prices. In September, a major producer lowered the basic cathode price to $2.00 for the larger cathode sizes and $2.05 for plating sizes. These prices were further lowered to $1.93 and $2.00 for melting and plating sizes, respectively, in November.

The domestic producer price for ferronickel stabilized at $1.88 by midyear but declined to $1.83 in November. Prices of imported ferronickel ranged at yearend from $1.83 to $1.86 for the several grades marketed in the United States. Yearend prices for other important product forms were: pellets, $1.93; briquets, $1.93; and Sinter 75 and steelmaking powders and briquets, $1.78.

Inco Ltd. in its annual report stated that the average realized price for all product forms sold in 1978 was $1.98, compared with $2.17 in 1977 and $2.15 in 1975.

With the rapid depletion of producer stocks early in 1979 caused by high demand, curtailed production, and the continuing major work stoppage, Inco Metals Co. reinstituted list prices in February. This action was followed by substantial price increases initiated by other major producers in March, April, May, and June. The June price levels, representing a 50% increase over February levels, persisted until early December when a final round of price increases averaging 6.7% was announced by all major producers. Yearend prices were $3.20 for melting cathode, pellets, and briquets ($3.25 for plating size cathode); $3.15 for domestic ferronickel; $3.19 to $3.26 for the more popular imported ferronickel grades; and $3.11 for nickel oxide sinter and steelmaking grades of powder and briquets. Computed average import prices, based upon custom declared value, for 1979 were $2.41 for cathode nickel, pellets, and briquets; $2.28 for ferronickel; and $2.51 for nickel oxide.

FOREIGN TRADE

The estimated contained nickel in U.S. exports of unwrought nickel, powders, flakes, and anodes in 1978 was about 9% of total primary demand in 1978 and 12% in 1979.

Canada remained the principal supplier of nickel to the United States in 1979, and accounted for 49% of total imports. The next most important sources in decreasing order of magnitude were Norway (Canadian matte source), Botswana (matte for domestic refining), New Caledonia, the Republic of South Africa, the Philippines, and Australia. In the aggregate, these seven countries accounted for 90% of U.S. imports. Imports declined in 1979 compared with 1978 because of a substantial liquidation of producer and merchant stocks.

World consumption of primary nickel was approximately 783,000 and 829,000 tons in 1978 and 1979, respectively. The prior record-high consumption was 783,000 tons in 1974.

Table 8.—U.S. exports of nickel and nickel alloy products, by class

Class	1977 Quantity (short tons)	1977 Value (thousands)	1978 Quantity (short tons)	1978 Value (thousands)	1979 Quantity (short tons)	1979 Value (thousands)
Unwrought	15,188	$68,212	11,641	$46,888	19,759	$106,743
Bars, rods, angles, shapes, sections	2,122	16,915	1,698	18,126	3,162	38,095
Plates, sheets, strip	3,997	32,217	4,387	35,943	5,379	52,558
Anodes	254	1,410	144	960	108	725
Wire	764	6,006	804	6,197	733	7,993
Powders and flakes	1,176	10,440	4,814	22,903	4,082	24,836
Foil	64	182	--	--	--	--
Catalysts	4,064	15,674	4,995	16,941	5,197	19,998
Tubes, pipes, blanks, and fittings thereof, and hollow bars	3,386	26,185	3,198	27,581	2,228	23,468
Waste and scrap	8,397	13,339	4,667	7,761	10,162	22,822
Total	39,412	190,580	36,293	183,250	50,810	297,233

Table 9.—U.S. imports for consumption of nickel products, by class

Class	1977 Quantity (short tons)	1977 Value (thousands)	1978 Quantity (short tons)	1978 Value (thousands)	1979 Quantity (short tons)	1979 Value (thousands)
Ore	111	$2	--	--	4,977	$12
Unwrought	103,269	451,582	147,664	$582,776	113,280	510,535
Oxide and oxide sinter	4,914	17,477	6,105	18,897	1,820	8,079
Slurry[1]	42,995	78,039	69,129	141,110	60,865	122,087
Bars, plates, sheets, anodes	947	6,048	183	1,049	1,937	13,249
Rods and wire	7,236	13,511	2,297	11,810	1,808	11,333
Shapes, sections, angles	11	55	9	63	14	142
Pipes, tubes, fittings	1,147	13,666	1,232	14,021	1,617	21,783
Powder	13,614	67,098	16,767	19,547	13,393	66,681
Flakes	146	610	214	890	784	3,522
Waste and scrap	3,175	6,546	3,694	10,117	3,596	16,634
Ferronickel	80,436	95,275	74,860	74,724	62,598	91,340
Total (gross weight)	258,001	749,909	322,154	925,004	266,282	865,397
Nickel content (estimated)	194,770	XX	[r]240,032	XX	183,742	XX

XX Not applicable.

[1] Nickel-containing material in slurry, or any form derived from ore by chemical, physical, or any other means, and requiring further processing to recover nickel or other metals; principally matte for refining.

Table 10.—U.S. imports for consumption of new nickel products, by country

(Short tons of nickel)

Country	Metal		Powder and flakes		Oxide and oxide sinter		Ferronickel		Slurry and other [1]	
	1978	1979	1978	1979	1978	1979	1978	1979	1978[e]	1979
Australia	7,302	6,817	5,226	4,371	--	--	--	--	--	2,583
Botswana	--	--	--	--	--	--	--	--	17,854	14,607
Canada	89,752	69,705	8,138	5,522	5,604	1,170	32	16	11,804	3,710
Dominican Republic	21	47	--	--	--	--	7,563	9,870	--	--
Finland	1,969	2,649	--	--	--	--	--	--	9	--
France	57	15	--	--	94	202	22	--	--	5
Germany, Federal Republic of	32	308	--	22	--	--	--	7	--	17
Japan	698	1,010	--	--	--	--	4,171	2,040	--	14
Netherlands	135	65	309	3	--	--	--	--	--	--
New Caledonia	--	--	--	--	--	--	8,998	6,840	6,964	3,288
Norway	27,397	16,017	--	20	--	7	38	--	11	--
Philippines	11,158	4,347	1,647	716	--	--	--	--	--	--
South Africa, Republic of	3,917	4,193	466	784	--	--	--	--	5,662	5,285
Sweden	316	77	--	--	406	--	--	--	358	31
United Kingdom	509	467	1,215	2,737	--	7	--	2	35	--
U.S.S.R	4,401	7,213	--	--	--	--	--	--	--	--
Other	--	350	--	1	1	19	81	--	--	29
Total	147,664	113,280	16,981	14,176	6,105	1,405	20,905	18,775	42,697	29,569

[e] Estimate.

[1] Nickel-containing material in slurry, or in any form derived from ore by chemical, physical, or any other means, and requiring further processing; principally matte for further refining; includes 96 short tons of nickel in salts in 1979; also includes 50 tons of nickel in laterite ores for testing purposes.

WORLD REVIEW

Australia.—Western Mining Corp. Ltd. (WMC) reduced operations early in 1978. Several small mines with limited reserves, including Scotia, Carr Boyd, and Fisher, were closed permanently and the lower grade ore operation at Kambalda was put on standby. Production of nickel during calendar year 1978 was estimated at 42,000 tons.

Open pit and underground operations at Windarra (jointly owned by WMC and Shell Australia Ltd.) were closed in February and June 1978, respectively, although drilling and underground development continued. The Agnew nickel mine, owned by Mt. Isa Mines Ltd. and Western Selcast (Pty.) Ltd., made initial shipments of concentrate to the Kalgoorlie smelter of WMC late in the year for toll conversion into matte for subsequent refining in the United States at the Amax Nickel Inc. refinery. Initial shipments of matte were received at the AMAX refinery in early 1979.

WMC completed the installation of a new shaft smelting furnace at the Kalgoorlie smelter in 1978. Total capacity of 450,000 tons per year of concentrate, equivalent to 90,000 tons per year of nickel in matte, is adequate to process the expected production from its own mines and the toll volume anticipated through 1985.

Legislation passed by the Queensland government again permitted refinancing for the Greenvale laterite nickel project of Queensland Nickel Pty. Ltd. The government-guaranteed loans totaled approximately A$90 million. The legislation permits repayments to international and Australian lenders of as low as 5% per year through 1980. Total indebtedness for the project approximated A$350 million in early 1978. Production from the Greenvale mine totaled 20,500 tons of nickel as 90% nickel oxide in 1978, compared with 18,500 tons in 1977.

Metal Exploration Ltd. accepted a $1.4 million loan from the Western Australia government to continue a four-year development program at the Nepean nickel mine south of Coolgardie. AMAX, Inc. continued exploratory drilling at the Digger Rocks sulfide deposit at Forrestania. Proven reserves of 1.3 million tons of ore have been defined grading 2.2% nickel at a cutoff grade of 1% nickel.

Botswana.—Continued operating losses at the Selebi Pikwe mine and smelter led to a restructuring of the indebtedness of Botswana RST, Limited. Amax Nickel, Inc., agreed to purchase the total matte produced. U.S. imports of matte from Botswana contained about 17,800 tons and 14,607 tons of nickel in 1978 and 1979, respectively, with the reduction in 1979 due to shipment curtailment in the last 4 months because of the work stoppage at the Louisiana refinery. These quantities represent nominal capacity operations at Selebi Pikwe.

Brazil.—Several new nickel projects have been under consideration in the last few years to develop nickel production capability to keep pace with projected requirements, principally for the expanding steel industry. Construction neared completion on a $100 million project to produce nickel carbonate by hydrometallurgical methods at a laterite site near Niquelandia. The carbonate would be shipped to a new electrolytic refinery near Sao Paulo. Annual capacity of the refinery was stated as 5,500 tons of cathode nickel, doubling to 11,000 tons with completion of a second stage in 1981.

The largest new project, at Barro Alto in Goias State, was halted by Inco Ltd., which had the majority interest in the development. Although the Baminco nickel deposit at Barro Alto is the largest known high-grade laterite deposit in Brazil, prospects were not considered promising because of excess production capacity in projects already completed elsewhere.

Burundi.—As a result of United Nations exploration activity, sizable deposits of laterite nickel ore have been discovered in the Musongati region. In late 1977, the United Nations awarded a contract to UOP, Inc. to carry out a feasibility study of extraction methods for the ore. During 1978, Ralph M. Parsons Co. carried out an engineering feasibility study, including capital cost and operating revenue estimates. Early in 1979, the Government of Burundi issued invitations to international mining companies to attend a conference in Bujumbura to consider the results of the feasibiltiy studies on a project that is based upon ore reserves of 200 to 300 million tons grading 1.5% nickel and estimated project cost of $850 million.

Canada.—Canadian nickel producers cut back operations drastically to achieve reduction of excess inventories that had accumulated since early 1975. By January 1978, several mines had been closed and other closings followed in the early months of the year. Final mining and milling capacity reductions occurred when the mine and mill of Inco Metals Co. (Inco) at Shebandowan, Ontario, were closed in September 1978. By midyear 1978, deliveries exceeded new

Table 11.—Nickel: World mine production, by country[1]

(Short tons)

Country	1976	1977	1978	1979[p]
Albania	7,700	8,300	8,800	9,400
Australia (content of concentrate)	[r]90,976	94,653	90,785	[2]81,570
Botswana	13,866	13,331	17,691	17,600
Brazil (content of ore)	5,812	4,675	3,924	4,400
Burma (content of speiss)	26	19	20	20
Canada[3]	265,464	256,300	143,360	[2]145,040
China, mainland[e]	10,000	11,000	11,000	11,000
Cuba (content of oxide and sulfide)[e]	[r]40,700	40,800	40,800	40,800
Dominican Republic	26,896	27,448	15,763	[2]27,650
Finland:				
Content of concentrate	7,008	6,434	4,859	6,400
Content of nickel sulfate	209	246	191	NA
German Democratic Republic	2,800	2,800	3,000	3,000
Greece (recoverable content of ore)[4]	30,380	28,243	24,140	22,700
Guatemala	--	328	2,000	9,520
Indonesia (content of ore)[4]	[r]31,716	36,468	35,179	[2]39,352
Mexico (content of ore)	62	87	24	22
Morocco (content of nickel ore and cobalt ore)	[r]161	172	192	187
New Caledonia (recoverable)[5]	[r]121,157	115,859	72,862	[2]89,550
Norway (content of concentrate)	579	550	1,100	550
Philippines	17,600	40,544	34,222	39,740
Poland (content of ore)[e]	3,100	3,100	3,100	3,100
Rhodesia, Southern (content of concentrate)[e]	17,600	17,600	17,600	17,600
South Africa, Republic of	24,660	24,201	24,250	24,250
U.S.S.R. (content of ore)[e]	[r]149,000	[r]157,000	163,000	168,000
United States (content of ore shipped)	16,469	14,347	13,509	15,065
Total	883,941	904,455	731,871	776,516

[e]Estimate. [p]Preliminary. [r]Revised. NA Not available.

[1] Insofar as possible, this table represents mine production of nickel; where data relate to some more highly processed form, the figure given has been used in lieu of unreported actual mine output to provide some indication of the magnitude of mine output, and are so noted parenthetically following the country name, or by footnote.

[2] Reported figure.

[3] Refined nickel and nickel content of oxides and salts produced, plus recoverable nickel in exported mattes and speiss.

[4] Includes a small amount of cobalt not reported separately.

[5] Nickel-cobalt content of metallurgical plant products, plus recoverable nickel-cobalt content of exported ores.

production. Reduction of inventories was accelerated by the strike of Inco employees in the Sudbury District. The strike began on September 16 and continued through June 15, 1979. Canadian mine production totaled 143,360 tons of nickel in 1978, a reduction of 44% from mine production in 1977. Mine production in 1979 was estimated at 145,000 tons.

Inco mined 10.9 million tons of ore in 1978, a reduction of 44% compared with 1977. Production of nickel was 134,000 tons compared with 208,000 tons in 1977, but shipments were up 21% to 188,700 tons.

The new $25 million powder metal strip plant of Inco's Canadian Alloys Division, Walden, Ontario, was commissioned during 1978. Small quantities of strip in several analyses were produced for customer trials for coinage and other applications.

Falconbridge Nickel Mines Ltd. (Falco) planned early in 1978 to reduce operations to 55% of capacity as a means of reducing inventories. Several mine closings were completed by the end of March. Production of ore was 2.28 million tons compared with 2.86 million tons in 1977, but shipments of nickel in 1978 were 37,440 tons compared with 17,440 tons in 1977. Inventories were reduced 44% by the end of 1978 compared with those at the end of 1977. Late in 1978, Falco announced that two mines would be reactivated to increase concentrate production approximately 10%. The increased flow of concentrates were to reach the smelter in May 1979. The large Lockerby mine was reactivated in late 1979. Nickel production by Falco from Canadian concentrates was 33,820 tons in 1979.

In the last quarter of 1978, Falco started marketing a button-shaped cathode form of nickel, termed Crowns, designed specifically for improved feeding in titanium baskets for continuous electroplating installations.

Both Inco and Falco instituted comprehensive energy management programs to control operating costs in the face of rapidly increasing electric power rates. A goal of 20% reduction in unit energy consumption was established for 1980.[4] [5]

Sherritt Gordon Mines Ltd. continued operations at its hydrometallurgical refinery at Fort Saskatchewan, Alberta. With the closure of the Lynn Lake, Manitoba, mine in 1977, the company was dependent on imported concentrates, principally from Western Australia. These supplies were cut off early in 1978 as the mines providing the principal feed were closed. Arrangements were subsequently made with Inco Ltd. to

Table 12.—Nickel: World smelter production, by country[1]

(Short tons)

Country[2]	1976	1977	1978[p]	1979[e]
Australia[3]	[r]43,947	37,633	41,146	[4]40,133
Botswana	(5)	(5)	(5)	(5)
Brazil[6]	2,369	2,789	2,811	2,600
Canada[7]	194,447	186,960	118,390	75,400
China, mainland[e]	10,000	11,000	11,000	11,000
Cuba[e]	[r]20,300	[r]20,400	19,800	19,800
Czechoslovakia[e]	3,900	4,400	4,400	4,400
Dominican Republic[6]	26,896	27,448	15,763	27,650
Finland	8,404	10,414	8,268	12,675
France[7]	13,573	11,331	8,684	3,860
German Democratic Republic[e]	3,100	3,100	3,300	3,300
Germany, Federal Republic of[8]	143	100	993	1,180
Greece[6]	18,131	10,582	16,645	20,800
Indonesia[6]	4,252	5,432	4,959	4,600
Japan	[r]104,499	108,507	87,303	112,000
Mexico	62	37	24	20
New Caledonia[9]	42,055	31,177	21,924	34,300
Norway	[r]36,029	42,132	26,166	33,820
Philippines	16,798	24,111	20,613	23,470
Poland[e]	3,100	3,100	3,100	3,100
Rhodesia, Southern[e]	11,000	14,300	14,300	14,600
South Africa, Republic of	18,700	19,000	19,300	19,300
United Kingdom	36,514	25,525	23,553	[4]20,594
U.S.S.R.[e]	[r]171,000	[r]179,000	185,000	190,000
United States[10]	[r]33,939	37,897	37,298	[4]41,293
Total	823,158	811,375	694,740	719,895

[e]Estimate. [p]Preliminary. [r]Revised.

[1] Refined nickel plus nickel content of ferronickel produced from ore and/or concentrates unless otherwise specified.

[2] In addition to the countries listed, Albania is known to have initiated smelter production in 1978, and North Korea is believed to have produced metallic nickel and/or ferronickel, but information is inadequate for formulation of reliable estimates of output levels. Several countries produce nickel-containing mattes, but output of nickel in such materials have been excluded from this table in order to avoid double counting. Countries producing matte include the following, with output indicated in short tons: Australia: 1976—35,260; 1977—36,650; 1978—36,045; 1979 (estimated)—36,400; Botswana: 1976—13,093; 1977—13,331; 1978—17,691; 1979 (estimated)—19,500; Indonesia: 1976—nil; 1977 (estimated)—3,120; 1978 (estimated)—7,280; 1979 (estimated)—11,100; New Caledonia: 1976—26,190; 1977—25,395; 1978—18,853; 1979 (estimated)—13,900.

[3] Refined nickel content of oxide.

[4] Reported figure.

[5] Data published in previous editions represented nickel content of copper-nickel matte, and has been deleted from table to avoid double counting. (This nickel has been reported as refined nickel output in countries that import matte from Botswana and process it into final smelter products).

[6] Nickel content of ferronickel only. (No refined nickel is produced.)

[7] Includes nickel content of ferronickel, refined nickel and nickel oxide.

[8] Includes nickel content of nickel alloys.

[9] Series revised to represent only the nickel content of ferronickel, omitting the nickel content of nickel matte that was included in previous editions; this has been done to avoid double counting.

[10] Byproduct of metal refining, including that derived from both domestic ores and imported materials.

provide feed stocks on a long-term basis from the Thompson area. Total refined nickel production was 13,460 tons in 1978, slightly higher than production in 1977, and 15,900 tons in 1979.

Colombia.—Final financing for Econiquel (Cerro Matoso S.A.) was arranged late in 1978, and it was announced that construction of the Montelibano ferronickel plant would begin in March 1979. Upon completion in 1982, the $360 million facility is expected to produce 21,000 tons per year of nickel in ferronickel for export. Participation in the project is distributed as follows: 45%, Econiquel; 35%, Billiton Overseas NV (a subsidiary of Shell-Netherlands); and 20%, Hanna Mining Co. Hanna will also hold the management contract.

Cuba.—Cuban production continued at the annual rate of 40,000 tons of contained nickel in two products— a nickel-cobalt matte which is shipped to Eastern Europe for further refining, and a finished nickel oxide sinter (76% nickel) which is shipped to Western and Eastern European countries. Expansion of the two complexes, previously known as Nicaro and Moa Bay, is underway with a planned annual combined capacity of 50,000 tons by 1981.

A second expansion phase involves a new integrated facility of 36,000 tons capacity at Punta Gorda which is reportedly under construction and scheduled to begin production in 1982. An additional new plant of similar capacity is to be constructed at Las Camaroicas with initial operation in 1984.

Dominican Republic.—Falconbridge Dominicana C. por A. operated at reduced capacity (about 45%) during 1978, and shipped 21,700 tons of nickel in ferronickel, compared with 22,700 tons in 1977. Reduced operations were necessitated by excess inventories; however, production rose to an estimated 27,650 tons in 1979. In late 1978, the company began marketing a new ferronickel product form, more suitable for mechanized handling; the individual cone-shaped pieces weigh about 1 1/2 pounds.

Finland.—Outokumpu Oy began commercial operations at the nickel-copper sulfide deposit at Vammala. Annual mine output of 400,000 tons of ore, averaging 0.7% nickel and 0.4% copper, replaces the company's former production at Vuonos. Total nickel production in 1978, all in the form of cathode nickel, was 8,268 tons. In 1979 production was estimated at 12,675 tons.

France.—The new electrolytic refinery of Société Métallurgique Le Nickel (SLN) near LeHavre, France, was completed in July 1978 and trial production was initiated in the last months of the year; production in 1978 totaled 2,490 tons of cathode nickel. Production was halted in late 1978 by a serious fire in the refinery. Production resumed in October 1979, and an estimated 3,000 tons of nickel was produced from October through December. The facility has a design capacity of 13,000 tons annually.

Greece.—Expansion of the Société Minière et Métallurguque de Larymna S.A. (LARCO) facility at Boeotia, from 15,000 to 27,000 tons annual capacity of nickel in ferronickel, was completed early in 1979. The expansion included the provision of modern haulage trucks, a new kiln and electric smelting furnace. A project on the Island of Euboea, east of Athens, was postponed pending improvement in market conditions for nickel. Also delayed were new facilities planned by Eleusi Bauxite Mines. Production of nickel by LARCO in 1978 was 14,887 tons compared with 10,600 tons in 1977; the latter figure reflected a 3-month labor strike. Production in 1979 approximated 20,800 tons. Most of the ferronickel product is exported to the European Community, Sweden, and Canada.

Guatemala.—A small matte shipment was made in February 1978 from the new plant of Exploraciones y Explotaciones Mineras Izabal, S.A. (Eximbal). After a short operating period to train personnel, the kiln and smelting furnace were shut down for inspection and modifications and restarted late in the year. Additional shipments were made totaling 1,585 tons to the newly installed fluidized bed roaster at Clydach, Wales. Production during 1979 was 7,000 tons of nickel in matte, mostly shipped to Clydach.

Indonesia.—Exports of nickel ore to Japan by P.T. Aneka Tambang, the Indonesia State mining corporation, were expected to total about 640,000 tons in the fiscal year ending May 31, 1979, compared with 830,000 tons in the previous fiscal year. The price for ore containing 2.4% nickel was $0.50 per pound of contained nickel, compared with $0.55 per pound in the previous fiscal year. Ferronickel production by Aneka Tambang in 1978 was equivalent to 4,349 tons, nickel content, and a similar volume was produced in 1979.

A Japanese consortium of nickel refining companies postponed plans to develop nickel laterite mining and ferronickel production facilities at Gebe Island in the Halmahera Group.

Construction was completed early in 1978 at the $900 million complex of P.T. International Nickel Indonesia at Soroako. One of the three process lines began operating in April, and the first shipment of high-nickel matte was made to Japan in May. Approximately 5,000 tons of nickel in matte were shipped in 1978, principally to Japan. Production in 1979 was 9,500 tons of nickel in 78%-nickel matte.

P.T. Pacific Nikkel Indonesia, the principals of which are United States Steel Corp., Hoogovens Ijmuiden B.V., Amoco Minerals Co., a subsidiary of Standard Oil of Indiana, and the Indonesian Government, completed exploration and preliminary engineering for nickel production on Gag Island off the northwest coast of Irian Java. With a projected capitalization of $1,000 million, the project is based upon 150 to 200 million tons of delineated ore and use of a modified Sherritt Gordon hydrometallurgical process with an annual production potential of 55,000 tons of nickel in the form of powder or briquets. Financing was not completed and the project was postponed.

Japan.—Japanese demand for nickel declined during most of 1978 but recovered modestly in the last 4 months. Producers of refined nickel began the year with excessive inventories of imported lateritic ore and refined nickel and ferronickel products. As a result, quantities of ore imported from New Caledonia, Indonesia, and Rio Tuba Nickel Mining Corp. of the Philippines were reduced substantially in the fiscal year ending in March 1979. In general, for ores averaging over 2% nickel, payment was made on the basis of $0.50 per pound of nickel contained, a decline of 9% from the prior year.

Japanese production averaged perhaps 50% of capacity in 1978. Further reductions were mitigated by the Special Metal Stockpiling Association program, which received a $49.5 million loan from Japan's Export-Import Bank to procure ore and matte and convert it to nickel and ferronickel. This program provided 1,155 and 14,800 tons of nickel and nickel in ferronickel, respectively, and 5,535 tons of nickel in high-nickel matte.

Nippon Mining Co. toll-refined 165,000 tons of ore for Aneka Tambang in 1978; the product was marketed as ferronickel by Philipp Bros., principally in the United States. Pacific Metals Corp. toll-refined an estimated 165,000 tons of ore in 1978. Shimura Kako postponed construction of a new refinery at Date because of depressed market conditions.

Overall Japanese demand for primary nickel was estimated at 97,000 metric tons in 1978, slightly higher than demand in 1977. However, the percentage of refined nickel imported increased because of the high operating costs of the Japanese producers, so that Japanese production for home consumption was 87,303 tons compared with 103,507 tons in 1977.

Japanese producers rebuilt stocks of laterite ore in 1979. A total of 3.3 million wet metric tons of ore was imported through September, with 51% from New Caledonia, 28% from Indonesia, and 21% from the Philippines. Total nickel consumption in 1979, based upon data for 10 months, was about 134,000 tons, of which 83,000 tons was in ferronickel, 33,000 tons in the form of pure nickel, and 8,000 tons as a nickel oxide sinter. Essentially all of the ferronickel and oxide sinter were consumed in production of wrought stainless and alloy steel products. Nickel consumption by product approximated: wrought stainless and alloy steel, 67%; cast stainless and high nickel alloys, 9%; electroplating, 9%; large cast and forged products, including mill rolls, 5%; electrical apparatus forgings and castings, 4%. Net imports of primary nickel products were comprised of 23,000 tons as ferronickel and 21,000 tons as cathode, pellets, powder, and briquets; with further increases in fuel prices and the cost of power, high domestic nickel prices ($3.87 per pound of cathode at yearend) were expected to lead to continued greater reliance on nickel imports.

New Caledonia.—Production of nickel ore declined in 1978 and 1979 compared with that of 1977 because of reduced requirements for ore by Japan and by SLN. SLN produced 40,777 tons of nickel in matte and ferronickel in 1978, compared with 56,600 tons in 1977. Sales of nickel in matte and ferronickel declined to 50,250 tons compared with 55,500 tons in 1977, resulting in a 27% reduction in sales value because of the lower volume and lower average realized prices.

In 1979, SLN and the independent miners produced approximately 4.0 million wet tons of ore (containing about 89,550 tons of nickel), of which 1.9 million tons was shipped to Japan. Ferronickel and matte production continued at about 60% of capacity, with the production of 34,500 tons of nickel in ferronickel and 13,700 tons of nickel in matte. Sales of ferronickel exceeded production, resulting in profitable operations during the last half of the year when higher prices prevailed.

AMAX Inc. and Bureau de Recherches Géologiques et Minières (BRGM) signed an agreement for joint development of nickel deposits at the north end of the island. Implementation of the agreement covers feasibility and financing studies and ultimate mine and plant construction and operation by PROMINES, a French company owned 51% by BRGM and 49% by AMAX. The deposits owned by PROMINES are located at Tiebaghi, Poum, and the Isle of Art. Reserves are conservatively estimated at 55 million tons of ore containing 2.5% nickel. AMAX announced that a sulfuric acid atmospheric and high-pressure leaching process would be applied to blends of the limonitic and garnieritic layers of the ore deposits. The facility may be operating by 1990.[6 7]

Philippines.—Production by Marinduque Mining and Industrial Corp. was curtailed during 1978 by the depressed nickel market. A total of 17,850 tons of nickel in briquet form was produced, plus 2,790 tons of nickel in mixed sulfide form, which was refined in Japan. Production in 1979 was 23,470 tons. Rio Tuba Nickel Mining Corp. shipped 675,000 wet tons of ore containing over 2% nickel to Japan in 1978, of which about 150,000 tons was converted to ferronickel for Rio Tuba's account by Pacific Metals Corp. Rio Tuba produced at an annual rate of 900,000 wet tons of ore in 1979.

Benguet Consolidated Inc. and Global Mining Resources Inc. control adjacent leases of an important laterite deposit in Zambales Province with delineated ore reserves of 35 million tons containing 1.8% nickel. Falconbridge Nickel Mines Ltd. will provide some equity for facilities and process technology. Feasibility studies have not been completed.

U.S.S.R.—Production capacity of the Norilsk nickel complex in Siberia reportedly will be expanded by 80% during the 10th 5-year plan, which started in 1977. This expansion will raise total Soviet capacity 44%, from 231,000 to 310,000 tons of nickel annually. New mine equipment is being installed, and the extraction and refining processes are being improved.

Yugoslavia.—The new ferronickel facility at Kavadarci, with rated annual capacity of 17,600 tons of nickel content, was scheduled to start operations late in 1979. Current indications suggest initial operations in 1982. A second mining and ferronickel production facility, in the Kosovo Republic bordering on Albania, was also under construction, with operations scheduled in 1982. Rekmk Kosovo is to mine 1.1 million tons of ore annually and produce 13,200 tons of nickel in ferronickel. Capital cost was estimated at $150 million.

TECHNOLOGY

Bureau of Mines scientists continued research on extraction methods for recovering nickel, copper, and platinum metals from matte produced from flotation concentrates from low-grade Duluth gabbro sulfide deposits. The matte treatment involves atmospheric and pressure leaching with sulfuric acid, separation of copper from nickel and cobalt by solvent extraction, and purification by electrowinning. Precious metals concentrate in the leach residue. The process developed by the Bureau for treatment of western laterite ores was carried to the pilot plant stage in October 1978 with a cost-sharing contract for $2.3 million with UOP, Inc., to modify a pilot plant at Tucson, Ariz., and carry out tests of the process over a 15-month period. Research continued on methods for extracting chromium from the leach residue after the nickel and cobalt have been recovered by leaching.

The Bureau continued research on methods of increasing recovery of nickel from wastes. The finalized procedure developed at the Rolla Research Center for recovering nickel, chromium, and iron from stainless steel plant particulates was demonstrated in several commercial-size electric-furnace heats. Recoveries of over 90% of the valuable elements as alloys were achieved by smelting pelletized mixtures of flue dusts, mill scale, grinding swarf, and reductant in electric furnaces. The Bureau provided technical assistance and monitored contracts with Inco Inc. and A.D. Little, Inc., with funds provided by the Federal Emergency Management Agency of the General Services Administration. The purpose of the project was to develop methods for extracting nickel, cobalt, and chromium from obsolete and contaminated superalloy and other high-nickel alloy scrap. Bureau researchers continued experimental work on practical methods of recovering nickel and cadmium in pure form from scrap nickel-cadmium batteries.

Development activities related to the mining of deep seabed nodules were slowed in 1978 because of the depressed nickel market and the discouraging outlook for an international agreement on rules for ocean mining. Ocean Mining Associates completed tests of an airlift system at depths of up to 15,000 feet; Ocean Minerals Co. contracted for lease of the ship "Glomar Explorer" and planned deepwater tests in early 1979. Ocean Management, Inc., completed two successful deepwater tests of a hydraulic lift system but subsequently announced deferment of activities. A Japanese consortium launched a ship specially designed for deep-sea nodule exploration, with initial operation expected southeast of Hawaii in July 1980. A survey paper on nodule resources in the northeastern equatorial Pacific Ocean was published.[8]

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Nitrogen

By Russell J. Foster[1]

Domestic ammonia production declined in 1978, but recovered to a record level in 1979. Consumption of ammonia in the United States continued upward, eclipsing previous peaks in both 1978 and 1979. Exports of ammonia and total nitrogen in compounds increased both years. Although total nitrogen-containing imports leveled off, the quantity of imported ammonia continued to rise. Industry overcapacity and rising costs, as well as low-priced imports, have confronted U.S. ammonia producers.

Legislation and Government Programs.—In July 1979, 12 U.S. producers and 1 distributor of ammonia petitioned the U.S. International Trade Commission for relief from Soviet imports under section 406 of the Trade Act of 1974. On October 11 the Commission reported to the President that market disruption did exist, and recommended a 3-year quota on U.S. imports of ammonia from the U.S.S.R. of 1.0 million tons in 1980, 1.1 million tons in 1981, and 1.3 million tons in 1982. However, on December 11, the President rejected the finding and recommendation.[2]

The Department of Energy approved the suggestion of W. R. Grace & Co. to change its proposed ammonia-from-coal plant at Henderson, Ky., to a commercial-size facility for the coal-based production of gasoline via methanol.[3]

The Natural Gas Policy Act of 1978 was enacted in October 1978. The measure, effective December 1, 1978, contains a decontrol provision based on a system of incremental price increases until 1985, when price controls on much of the natural gas will be lifted. The act assures that essential agricultural users of natural gas will receive priority second only to residential, school, and hospital use, in the event of curtailments.[4]

In March 1978 the Federal Energy Regulatory Commission (FERC) ruled that natural gas from Federal offshore sources must be offered to the interstate market and could not be reserved for the producer or specific customers.[5] In June 1979 FERC announced that approval for First Mississippi Corp. and its partners to use Federal offshore natural gas for their joint-venture ammonia plant at Donaldsonville, La., would be contingent on the companies' agreeing to offer natural gas from other sources to the interstate pipelines that will transport the gas to the plant.[6]

The Environmental Protection Agency (EPA) established effluent limitations guidelines for ammonia and ammonium

Table 1.—Salient ammonia statistics

(Thousand short tons of contained nitrogen)

	1975	1976	1977	1978	1979[p]
United States:					
Production[1]	[r]13,609	[r]13,856	14,712	14,232	14,932
Exports	289	361	346	434	649
Imports for consumption	662	599	884	1,247	1,603
Consumption[2]	[r]13,223	[r]13,939	14,831	15,270	16,178
World: Production	[e]54,600	62,600	68,500	72,800	77,200

[e]Estimate. [p]Preliminary. [r]Revised.

[1]Synthetic anhydrous ammonia and coke oven ammonia.

[2]Includes producers' stock change in synthetic anhydrous ammonia and coke oven ammonia.

sulfate representing the degree of effluent reduction attainable by the application of the best conventional pollutant control technology.[7] EPA withdrew regulations which established pH parameters for urea and ammonium nitrate plants until the industry petition for reconsideration of the regulations can be fully evaluated.[8]

Effective in November 1978, the Occupational Safety and Health Administration established final standards limiting worker exposure to acrylonitrile at 2 parts per million averaged over 8 hours.[9]

DOMESTIC PRODUCTION

Production of ammonia in the United States declined to 14.2 million tons of nitrogen content in 1978. Industry overcapacity and an influx of low-priced imports from countries with plentiful supplies of inexpensive feedstock exerted downward pressure on prices. Coupled with rising costs, especially for natural gas, these factors caused several domestic ammonia plants to shut down or reduce output. Stronger ammonia demand in 1979 spurred production to an alltime high of 14.9 million tons of contained nitrogen.

Construction of new ammonia plants for American Cyanamid Co., at Fortier, La., Columbia Nitrogen Corp., at Augusta, Ga., and Georgia Pacific Corp., at Plaquemine, La., was completed during 1978-79, after substantial new capacity was added in 1977.

Table 2.—Fixed nitrogen production in the United States

(Thousand short tons of contained nitrogen)

	1975	1976	1977	1978	1979[p]
Anhydrous ammonia, synthetic plants[1]	[r]13,496	[r]13,741	14,602	14,129	14,826
Ammonium compounds, coking plants:					
Ammonia liquor	5	4	7	7	6
Ammonium sulfate	108	111	103	96	100
Ammonium phosphates	(2)	(2)	(2)	(2)	(2)
Total	[r]13,609	[r]13,856	14,712	14,232	14,932

[p]Preliminary. [r]Revised.

[1]Current Industrial Reports, U.S. Department of Commerce, Bureau of the Census.

[2]Included with ammonium sulfate to avoid disclosing company proprietary data.

Table 3.—Major nitrogen compounds produced in the United States

(Thousand short tons, gross weight)

Compound	1977	1978	1979[p]
Acrylonitrile	821	876	1,009
Ammonium nitrate	7,177	7,210	7,796
Ammonium sulfate[1]	2,748	2,900	[e]2,400
Ammonium phosphates	10,211	11,517	12,082
Nitric acid	7,987	7,934	8,559
Urea	4,446	6,506	6,749

[e]Estimate. [p]Preliminary.

[1]Includes ammonium sulfate from coking plants.

Sources: Bureau of the Census and International Trade Commission.

Table 4.—Domestic producers of anhydrous ammonia

(Thousand short tons per year of ammonia)

Company	Location	Capacity
Agrico Chemical Co. - Williams	Blytheville, Ark	407
Do	Donaldsonville, La	468
Do	Verdigris, Okla	840
Air Products & Chemicals, Inc	New Orleans, La	210
Do	Pace Junction, Fla	100
Allied Chemical Corp	LaPlatte, Nebr	172
Do	Hopewell, Va	340
Do	Geismar, La	340
Do	Helena, Ark	210
American Cyanamid Co	Fortier, La	580
Amoco Oil Co	Texas City, Tex	522
Apache Powder Co	Benson, Ariz	15
Atlas Chemical Industries, Inc	Joplin, Mo	136
Beker Industries Corp	Conda, Idaho	100
Borden Chemical Co	Geismar, La	340
Camex, Inc	Borger, Tex	400
Car-Ren, Inc	Columbus, Miss	68
CF Industries, Inc	Donaldsonville, La	1,590
Do	Fremont, Nebr	48
Do	Terre Haute, Ind	150
Do	Tunis-Ahoskie, N.C	210
Do	Tyner, Tenn	170
Chevron Chemical Co	Pascagoula, Miss	510
Do	Fort Madison, Iowa	105
Do	El Segundo, Calif	20
Columbia Nitrogen Corp	Augusta, Ga	510
Diamond Shamrock Chemical Co	Dumas, Tex	160
Dow Chemical Co	Freeport, Tex	115
E. I. du Pont de Nemours & Co	Beaumont, Tex	340
Do	Victoria, Tex	100
El Paso Products Co	Odessa, Tex	115
Farmland Industries, Inc	Fort Dodge, Iowa	210
Do	Dodge City, Kans	210
Do	Hastings, Nebr	140
Do	Enid, Okla	840
Do	Lawrence, Kans	340
Do	Pollock, La	420
Felmont Oil Corp	Olean, N. Y	85
First Mississippi Corp	Fort Madison, Iowa	365
FMC Corp	S. Charleston, W. Va	24
Gardinier, Inc	Tampa, Fla	120
Georgia Pacific Corp	Plaquemine, La	196
Goodpasture, Inc	Dimmitt, Tex	40
W. R. Grace & Co	Woodstock, Tenn	340
Green Valley Chemical Co	Creston, Iowa	35
Hawkeye Chemical Co	Clinton, Iowa	138
Hercules, Inc	Louisiana, Mo	70
Hooker Chemical Co	Tacoma, Wash	23
International Minerals & Chemical Corp	Sterlington, La	400
Jupiter Chemical Co	Lake Charles, La	78
Kaiser Agricultural Chemicals Co	Savannah, Ga	100
Mississippi Chemical Corp	Yazoo City, Miss	393
Do	Pascagoula, Miss	175
Monsanto Co	Luling, La	850
New Jersey Zinc Co	Palmerton, Pa	35
N-Ren Corp	Pryor, Okla	94
Do	East Dubuque, Ill	238
Do	Carlsbad, N. Mex	68
Occidental Agricultural Chemical Co	Taft, La	90
Oklahoma Nitrogen Co	Woodward, Okla	400
Olin Corp	Lake Charles, La	490
Pennwalt Chemical Co	Portland, Oreg	8
Phillips Pacific Chemical Co	Kennewick, Wash	155
Phillips Petroleum Co	Beatrice, Nebr	210
PPG Industries	Natrium, W. Va	50
Reichhold Chemicals, Inc	St. Helens, Oreg	90
J. R. Simplot Co	Pocatello, Idaho	108
Tennessee Valley Authority	Muscle Shoals, Ala	74
Terra Chemicals International, Inc	Port Neal, Iowa	210
Triad Chemical Co	Donaldsonville, La	340
Union Oil Co	Kenai, Alaska	1,020
Do	Brea, Calif	280
U.S.S. Agri-Chemicals, Inc	Clairton, Pa	325
Do	Cherokee, Ala	175
Do	Geneva, Utah	70
Valley Nitrogen Producers, Inc	El Centro, Calif	210
Vistron Corp	Lima, Ohio	475
Wycon Chemical Co	Cheyenne, Wyo	167
Total		20,365

Source: Economics and Marketing Research Section, Tennessee Valley Authority. World Fertilizer Capacity, Ammonia. Muscle Shoals, Ala., Apr. 16, 1980.

CONSUMPTION AND USES

Domestic consumption of ammonia increased to 15.3 million tons of contained nitrogen in 1978. This rise in ammonia demand was due primarily to greater production of nitrogen fertilizers for export, as domestic fertilizer application was down. In 1979 ammonia consumption reached nearly 16.2 million tons of nitrogen content because of greater use of nitrogen fertilizers in the United States and the continued strength of export markets.

Fertilizers account for over three-fourths of ammonia demand either in direct application or the manufacture of downstream compounds. Other uses of chemicals produced from ammonia include explosives, resins, fibers, plastics, and animal feeds.

STOCKS

Ammonia stocks held by producers at yearend 1978 totaled over 2.0 million tons of contained nitrogen, down 10% from the previous year's ending inventory. In 1979 stocks of ammonia were reduced 14% further to just under 1.8 million tons of nitrogen content at yearend.

PRICES

Abundant supplies and reduced demand by domestic agriculture depressed ammonia prices throughout 1978. The spot market reportedly declined to about $80 per ton, f.o.b. gulf coast.[10] In the spring of 1978 the average price of ammonia at the farm level was down more than 9% from a year earlier, and dropped further during the year. Prices paid by U.S. farmers for nitrogen fertilizer compounds were mixed compared with those of the previous year. However, a general decline was observed through the remainder of the year.[11]

Improved demand enabled ammonia prices to recover throughout 1979, reaching about $130 per ton, f.o.b. gulf coast by yearend.[12] By spring 1979 the average price of ammonia at the farm level had risen 6% from the year before, and continued to climb as the year went on. Except for solutions, spring farm prices of nitrogen fertilizers were higher than those of the previous year, and all compounds displayed increases during the year.[13]

Table 5.—Price quotations for major nitrogen compounds at yearend 1978-79

(Per short ton)

Compound	Price	
	1978	1979
Anhydrous ammonia:		
f.o.b. gulf coast	$80- 84	$128-132
Delivered Corn Belt	104-115	148-155
Ammonium sulfate: f.o.b. Corn Belt	60- 65	75- 80
Ammonium nitrate: Delivered Corn Belt	86- 90	118-120
Urea:		
f.o.b. gulf coast	106-110	145-150
Delivered Corn Belt	125-135	165-170
Diammonium phosphate: f.o.b. Tampa	116-120	212-215

Source: Green Markets.

FOREIGN TRADE

The quantity of ammonia exported by the United States increased substantially in both 1978 and 1979. In addition, greater exports of downstream nitrogen products, especially ammonium phosphates, urea, ammonium sulfate, and nitrogen solutions, contributed to record levels of total fixed nitrogen exports in both years.

U.S. ammonia imports also attained new highs in 1978 and 1979. Soviet shipments began in January 1978, and by yearend 1979 the U.S.S.R. was the leading foreign supplier of ammonia to the United States, followed by Canada, Trinidad and Tobago, and Mexico. The amount of other nitrogen compounds imported has declined.

Table 6.—U.S. exports and imports for consumption of major nitrogen compounds

(Thousand short tons and thousand dollars)

Compounds	1978 Gross weight	1978 Nitrogen content[e]	1978 Value	1979 Gross weight	1979 Nitrogen content[e]	1979 Value
EXPORTS						
Industrial chemicals:						
Ammonia, aqua (ammonia content)	3	2	320	2	2	232
Ammonium nitrate	8	3	561	8	3	519
Ammonium phosphates	45	8	7,879	13	2	5,576
Ammonium sulfate	18	4	1,009	9	2	468
Fertilizer materials:						
Ammonium nitrate	38	13	4,168	100	33	10,724
Diammonium phosphate	4,331	780	525,610	4,438	799	676,194
Other ammonium phosphates	506	56	54,229	493	54	70,382
Ammonium sulfate	807	169	47,858	1,034	217	54,746
Anhydrous ammonia	525	432	40,297	788	647	88,335
Sodium nitrate	34	5	5,726	62	10	3,431
Urea	1,514	696	144,895	1,503	691	181,359
Nitrogen solutions	27	9	2,245	374	120	24,733
Other nitrogen fertilizers	163	33	11,308	42	8	4,477
Mixed chemical fertilizers	219	22	33,176	352	35	50,318
Total[1]	8,239	2,232	879,279	9,218	2,624	1,171,494
IMPORTS						
Industrial chemicals:						
Anhydrous ammonia and chemical-grade aqua	14	12	855	([2])	([2])	68
Ammonium nitrate	76	27	6,430	104	36	8,884
Ammonium phosphate	3	1	1,176	4	1	1,579
Ammonium sulfate	([2])	([2])	25	([2])	([2])	20
Fertilizer materials:						
Ammonium nitrate	404	135	33,470	277	93	24,272
Ammonium nitrate-limestone mixtures	([2])	([2])	9	--	--	--
Diammonium phosphate	119	21	14,335	145	26	17,898
Other ammonium phosphates	207	23	22,074	200	22	24,459
Ammonium sulfate	326	68	19,770	245	51	16,893
Calcium cyanamide or lime nitrogen	2	([2])	412	2	([2])	440
Calcium nitrate	100	15	5,605	123	18	6,931
Nitrogen solutions	331	106	32,950	120	38	12,385
Anhydrous ammonia	1,502	1,235	132,686	1,951	1,603	166,122
Potassium nitrate	73	10	8,468	36	5	4,327
Potassium nitrate, sodium nitrate mixtures	29	4	2,935	42	6	4,000
Sodium nitrate	142	23	11,602	116	19	10,019
Urea	1,426	656	169,300	1,129	519	136,781
Other nitrogenous fertilizers	109	22	13,570	45	9	6,443
Mixed chemical fertilizers	168	17	20,232	197	20	26,245
Total[1]	5,032	2,374	495,905	4,737	2,468	467,766

[e] Estimate.

[1] Data may not add to totals shown because of independent rounding.

[2] Less than 1/2 unit.

WORLD REVIEW

Recent major expansions in the ammonia industry worldwide have resulted in overcapacity. Centrally planned economy countries, particularly the U.S.S.R., and developing nations have been claiming an increasingly greater share of world ammonia supply capability. A large portion of this new capacity is based on abundant supplies of low-cost feedstock, and much of the output is intended for export markets at very competitive prices. In fact, world ammonia trade grew markedly in 1978 and 1979, with the Soviets emerging as the world leader in ammonia exports. Production problems at various locations, including the U.S.S.R., Mexico, and the Netherlands, along with escalating naphtha costs, contributed to a tightening of world supply and higher world ammonia prices during 1979.

Abu Dhabi.—A contract was awarded for the construction of a 1,100-ton-per-day ammonia plant and a 1,650-ton-per-day urea unit by 1981.[14]

Algeria.—An ammonia plant with a capacity of 300,000 tons per year of nutrient was under construction at Arzew along with downstream units.[15]

Bahrain.—A joint venture, Bahrain-Kuwait Petrochemical Industries, was formed to construct and operate a 1,100-ton-per-day ammonia plant at Sitra using natural gas feedstock.[16]

Bangladesh.—A natural-gas-based ammonia/urea complex with annual capacities of 300,000 and 267,000 tons of contained nitrogen, respectively, is anticipated onstream at Ashuganj in 1980.[17] A 1,100-ton-per-day ammonia plant, which will utilize natural gas from the Bakhrabad field, and downstream 1,900-ton-per-day urea unit are planned for Chittagong in the early 1980's.[18] Mainland China agreed to help construct a small-scale ammonia/urea facility at Ghorashal.[19]

Bolivia.—Plans for two ammonia/urea complexes were announced in 1978. An ammonia plant with a capacity of 300,000 tons per year nitrogen content and a urea unit with 152,000 tons per year of nitrogen capacity were slated onstream in 1982 at Puerto Suarez. A small-scale facility was planned at Rio Grande.[20]

Brazil.—Petrobras awarded a contract for the design and construction of a coal gasification plant at San Jeronimo, Rio Grande do Sul State, by 1983. Coal from the mines at Leao will be converted to synthesis gas using the Koppers-Totzek process for the production of 660 tons of ammonia per day.[21]

Bulgaria.—Contracts were signed for a 400-ton-per-day ammonia synthesis gas preparation unit and a 600-ton-per-day urea plant. The facility will be constructed at Vratsa by 1981.[22]

Burma.—A natural-gas-based ammonia plant with annual capacity of 107,000 tons of contained nitrogen and a urea unit with 100,000 tons of annual nutrient capacity have been scheduled onstream in 1983.[23]

Canada.—Esso Chemical Canada announced plans to begin construction of a 1,100-ton-per-day ammonia plant and a 1,650-ton-per-day urea unit in Alberta during 1981, with startup in 1983.[24]

China, Mainland.—With the completion of two facilities in 1979, all 13 large ammonia/urea complexes purchased from abroad in the early 1970's have been completed.[25] Contracts for four additional 1,100-ton-per-day ammonia plants, three based on fuel oil and one on coal gasification, have been awarded, and more are anticipated.[26]

Colombia.—Plans were announced for a 1,100-ton-per-day ammonia plant and a 1,650-ton-per-day urea plant at Guagira.[27]

Cuba.—Construction of a 1,430-ton-per-day ammonia plant and two 1,100-ton-per-day urea units at Cienfuegos has been proposed. The complex would utilize naphtha feedstock from local refineries.[28]

Egypt.—Production from Abu Qir Fertilizer & Chemical Products' ammonia plant with a capacity of 364,000 tons per year of contained nitrogen and a urea unit with annual nutrient capacity of 259,000 tons, began in 1979 at Abu Qir. The Talkha II project, consisting of an ammonia plant with annual nitrogen content capacity of 353,000 tons and a urea plant with 286,000 tons of nutrient capacity annually, should be onstream in 1980.[29]

France.—An ammonia plant with annual contained nitrogen capacity of 300,000 tons was brought onstream in 1979 at the Grand Quevilly site of Rhone-Poulenc Industries, which will share the output with CdF Chimie and Cie. Francaise de l'Azote.[30]

Germany, Federal Republic of.—An ammonia plant jointly owned by Superfos A/S and Veba Chemie AG, rated at 496,000 tons per year of contained nitrogen, came onstream at Brünsbuttel in 1978.[31] BASF will replace some older oil-based ammonia units at Ludwigshafen with a new natural-gas-fed plant having a nitrogen content capacity of 408,000 tons per year.[32]

Greece.—Plans to construct a 1,100-ton-per-day ammonia plant at Kavalla by 1982 were announced.[33]

India.—The government has decided to grant first priority to natural gas as a fertilizer feedstock, followed by coal and naphtha.[34]

The Fertilizer Corp. of India (FCI) brought a 900-ton-per-day, fuel-oil-based ammonia plant and downstream urea unit with a capacity of 167,000 tons of nutrient per year, onstream at Nangal early in 1978.[35] Two facilities utilizing coal as feedstock were completed at Talcher and Ramagundam for FCI in 1979, with annual capacities of 269,000 tons of contained nitrogen for the ammonia plants and 251,000 tons nitrogen content of urea.[36] Modernization of FCI's complex at Sindri was completed in 1979, raising annual ammonia and urea capacities to 168,000 tons and 309,000 tons of nitrogen content, respectively.[37]

The Gujarat State Fertilizer Corp. awarded a contract for the construction of a 1,485-ton-per-day ammonia plant and a 1,765-ton-per-day urea unit at Broach.[38]

A third nitrogen fertilizer facility will be constructed for Hindustan Fertilizer Corp. at Namrup by 1982. Gas from the Assam oilfields will be used as feedstock for a 180,000-ton-per-year-nitrogen ammonia plant and a 168,000-ton-per-year-nitrogen urea unit.[39]

Indian Explosives Ltd. announced plans to expand its annual ammonia and urea capacities at Kanpur by 50% to 373,000 tons and 342,000 tons of contained nitrogen, respectively.[40]

The Indian Farmers Fertilizer Cooperative Ltd. (IFFCO) contracted for the installation of two 1,485-ton-per-day, natural-gas-based ammonia plants and two downstream urea units at Hajira by 1983.[41] IFFCO commissioned a 269,000-ton-per-year-nitrogen ammonia plant and a 260,000-ton-per-year-nitrogen urea unit at Phulpur in 1979.

A 269,000-ton-per-year-nitrogen ammonia plant and a 251,000-ton-per-year-nitrogen urea unit were under construction at Kakinada for Nagarjuna Fertilizers.[42]

National Fertilizers Ltd. brought ammonia/urea facilities onstream at Panipat and Bhatinda in 1979 with daily capacities of 990 tons of ammonia and 1,650 tons of urea.[43]

A large ammonia/urea complex will be built at Thal-Vaishet for Rashtriya Chemicals & Fertilizers based on natural gas from the Bombay High field. Two 1,488-ton-per-day ammonia plants and three 1,650-ton-per-day urea units are scheduled for completion in 1983.[44]

Indonesia.—The PUSRI IV project, consisting of an ammonia plant with 300,000 tons per year of contained nitrogen capacity and a urea unit rated at 289,000 tons per year of nitrogen content, came onstream in 1978 at Palembang.[45] An identical complex was dedicated at yearend 1978 at Cikampek, West Java.[46] Contracts were awarded for the construction of a grassroots, natural-gas-based complex at East Kalimantan. The 1,650-ton-per-day ammonia plant and 1,870-ton-per-day urea unit are scheduled for startup in 1982.[47] The Association of Southeast Asian Nations (ASEAN) and the government of Japan will jointly finance the construction of a 300,000-ton-per-year-nitrogen ammonia plant and a 289,000-ton-per-year-nitrogen urea unit at Aceh, North Sumatra. The facility is slated for 1984.[48]

Iraq.—Two ammonia plants, rated at 300,000 tons per year of contained nitrogen and two downstream urea units with a capacity of 272,000 tons per year of nutrient were brought onstream at Khor Al Zubair in 1979. This signals the emergence of Iraq as a significant urea exporter.[49] Consideration is being given to constructing a 45,000-ton-per-year-nitrogen ammonia plant at Al Qaim to provide onsite material for that fertilizer complex.[50]

Ireland.—A facility consisting of a 1,485-ton-per-day ammonia plant and a 1,100-ton-per-day urea unit was brought onstream at Marino Point in 1979.[51]

Japan.—The development of new nitrogen fertilizer capacity in Asia and the escalation of energy costs has adversely affected Japan's position as a major supplier of nitrogen fertilizers to world markets. A plan submitted by the Industry Structure Council, and approved by the Ministry of Trade and Industry early in 1979, will result in the reduction of ammonia capacity by 27% and urea capacity by 43%.[52]

Kuwait.—Petrochemical Industries Co. awarded a contract in connection with the construction of a 1,100-ton-per-day ammonia plant at Shuaiba.[53]

Libya.—The National Oil Corp. awarded a contract for the construction of another 1,100-ton-per-day ammonia plant at Marsa el Brega by 1981.[54]

Malagasy Republic.—The government and N-Ren Corp. announced a joint venture to construct a naphtha-based ammonia plant and downstream 99,000-ton-per-year urea plant at Tamatave.[55]

Malaysia.—ASEAN approved the construction of a 300,000-ton-per-year-nitrogen ammonia plant and a 289,000-ton-per-year-nitrogen urea unit at Dintulu, Sarawak.[56]

Mexico.—After bringing onstream two ammonia plants at Cosoleacaque and one at Salamanca during 1977 and 1978, Petroleos Mexicanos (PEMEX) announced plans to construct four additional plants. Two of the 490,000-ton-per-year units, originally slated for Cunduacan, will be located at Cosoleacaque by 1981.[57] Operational difficulties at some plants required PEMEX to reduce export shipments in the spring of 1979.[58]

New Zealand.—Contracts were awarded for the construction of a nitrogen fertilizer facility at Kapuni. A 101,000-ton-per-year ammonia plant and a 170,000-ton-per-year urea unit, to be operated by Petrocorp, a subsidiary of the Natural Gas Corp. of New Zealand, are scheduled onstream in 1981.[59]

Nigeria.—The Federal Ministry of Industry awarded letters of intent to three U.S. companies to construct a fertilizer complex at Port Harcourt and to market the output. The 1,100-ton-per-day ammonia plant, 1,650-ton-per-day urea plant, and mixed fertilizer unit were scheduled onstream in 1984.[60]

Pakistan.—A 1,000-ton-per-day ammonia plant and a 240-ton-per-day urea unit came onstream for Pak-Arab Fertilizers in 1978 at Multan, followed by other downstream facilities. Paksaudi Fertilizers commissioned a 1,100-ton-per-day ammonia plant and a 1,918-ton-per-day urea unit at Mirpur

Mathelo in 1979.[61]

Pakistan Ajman Fertilizer Corp. contracted for a prefabricated ammonia/urea facility at Lasbela. Developed by the Swedish shipbuilder Svenska Varv and the Danish engineering firm Haldor Topsoe, the 1,100-ton-per-day ammonia plant and 1,900-ton-per-day urea unit will be built at Goetaverken, Sweden, and towed to the site.[62]

Fauji Fertilizer Co. awarded contracts for the construction of a 300,000-ton-per-year-nitrogen natural-gas-based ammonia plant and a 279,000-ton-per-year-nitrogen urea unit at Goth Macchi by 1981.[63]

Plans for additional ammonia/urea complexes at Sadiqabad, Chickoki, and Port Qaim have also been announced.[64]

Poland.—A plan to construct a nitrogen fertilizer facility at Kedzierzyn was revived, based on natural gas, not coal as originally conceived. The project will comprise a 1,650-ton-per-day ammonia plant and three 990-ton-per-day urea units, using Polish processes.[65]

Portugal.—A contract was awarded for the construction of a 269,000-ton-per-year-nitrogen ammonia plant at Lavradio for Quimica de Portugal E.P. When completed in 1982, the new fuel-oil-based plant will replace an existing 59,000-ton-per-year-nitrogen unit.[66]

Qatar.—The new Umm Said complex, a natural-gas-based ammonia plant rated at 269,000 tons per year of contained nitrogen and a urea plant with a capacity of 168,000 tons per year of nutrient came onstream in 1979, doubling capacity at the site.[67]

Saudi Arabia.—A preliminary design contract was awarded for the construction of a 1,100-ton-per-day, natural-gas-based ammonia plant, and a 1,760-ton-per-day urea unit by mid-1982 at Al-Jubail. Under terms of an agreement signed with Saudi Basic Industries Corp., Taiwan Fertilizer Co. will take 60% of the urea plant's annual output in return for partial financing and operating the complex.[68]

Sri Lanka.—Construction of a naphtha-based ammonia plant, with a capacity of 162,000 tons per year of contained nitrogen, and downstream 158,000-ton-per-year-nitrogen urea unit was begun in 1978 at Sapugaskanda.[69]

Syria.—General Fertilizers Co. began production at the Homs ammonia/urea facility at yearend 1979. Annual capacities in terms of nitrogen content are 300,000 tons of ammonia and 175,000 tons of urea.[70]

Trinidad and Tobago.—Fertilizers of Trinidad and Tobago Ltd., a joint venture of the government and Amoco Oil Co., awarded a contract for the construction of two ammonia plants with total capacity of 2,300 tons per day at Port Lisas by 1981. The government and Agrico Chemical Co. agreed to build a 1,785-ton-per-day urea plant at the site also.[71]

Turkey.—Istanbul Gubre Sanayii has again proposed a 1,100-ton-per-day naphtha-based ammonia plant and a 1,930-ton-per-day urea unit at Kirikkale.[72]

U.S.S.R.—From 1973 through 1979, 26 1,500-ton-per-day ammonia plants, procured from foreign contractors, have been installed. Four more are due to be commissioned in 1980, and 10 additional units have been ordered for construction during 1981-85. Substantial quantities of ammonia have been slated for export to the United States and other countries.[73]

Production problems attributed to several factors including severe winter weather and disruption of natural gas supplies from Iran resulted in the curtailment of Soviet ammonia exports early in 1979.[74]

Yugoslavia.—Plans for the construction of a 1,100-ton-per-day, natural-gas-based ammonia plant and a 1,100-ton-per-day urea unit at Sabac were announced.[75] Contracts were awarded for the construction of a 440,000-ton-per-year-nitrogen ammonia plant and downstream facilities at Kutina by 1981. A 300,000-ton-per-year-nitrogen ammonia plant was purchased from Sefanitro in Spain when construction at their Bilbao site was halted, and will be installed at Pancevo.[76]

Table 7.—Ammonia: World production by country

(Thousand short tons of contained nitrogen)

Country	1976	1977	1978[p]	1979[e]
North America:				
Canada	1,258	1,959	2,172	[1]2,184
Cuba[e]	100	100	100	150
Mexico	789	860	1,437	1,500
Netherlands Antilles	93	37	--	--
Trinidad and Tobago	180	195	442	[1]428
United States	13,856	14,712	14,232	[1]14,932
South America:				
Argentina	41	46	52	50
Brazil	159	160	224	250
Colombia	100	72	70	100
Peru[e]	83	91	89	90
Venezuela	280	299	299	300
Europe:				
Albania[e]	40	40	40	40
Austria	503	513	518	520
Belgium	594	643	543	600
Bulgaria	1,015	1,097	1,058	1,200
Czechoslovakia	799	872	901	900
Denmark	36	36	36	36
Finland	185	145	165	170
France	1,963	2,242	2,223	2,300
German Democratic Republic	1,233	1,246	1,253	1,300
Germany, Federal Republic of	2,053	2,192	2,155	2,300
Greece	262	248	252	250
Hungary	775	804	822	830
Iceland[e]	9	7	8	8
Ireland	38	31	26	200
Italy	1,344	1,287	1,591	1,600
Netherlands[2]	2,183	2,359	2,388	2,400
Norway	522	556	580	600
Poland	1,903	1,835	1,775	1,800
Portugal	175	203	278	280
Romania	1,829	1,975	2,488	2,600
Spain	1,158	1,063	970	900
Sweden	119	112	105	110
Switzerland[e]	50	50	50	50
U.S.S.R	11,122	11,843	12,456	13,400
United Kingdom	1,485	1,798	1,764	1,800
Yugoslavia	427	460	[e]450	450
Africa:				
Algeria	23	--	--	50
Egypt	[e]230	231	276	380
Libya[e]	--	--	90	100
South Africa, Republic of	518	560	621	620
Zambia[e]	20	20	20	20
Zimbabwe-Rhodesia[e]	80	80	70	70
Asia:				
Afghanistan[e]	40	40	30	30
Bangladesh	163	110	116	190
Burma[e]	60	60	60	60
China:				
Mainland[e]	4,500	6,200	7,400	7,900
Taiwan	352	359	483	510
India[3]	2,105	2,245	2,447	2,900
Indonesia	204	452	644	1,000
Iran	254	299	196	100
Iraq	[e]150	150	200	500
Israel	[e]71	76	75	75
Japan	2,465	2,526	2,705	2,300
Korea, North[e]	300	450	500	500
Korea, Republic of	666	799	989	1,000
Kuwait	465	443	475	480
Malaysia	47	37	44	45
Pakistan	360	348	341	[1]425
Philippines[e]	90	90	90	90
Qatar	[e]100	116	183	350
Saudi Arabia	[e]112	138	154	160
Syria	[e]25	25	21	80
Thailand[e]	8	8	10	--
Turkey	[e]100	118	239	250
Vietnam[e]	--	10	20	25
Oceania: Australia	339	348	324	340
Total	62,600	68,500	72,800	77,200

[e] Estimate. [p] Preliminary.

[1] Reported figure.

[2] Data as reported by International Superphosphate Manufacturers' Association (ISMA); official Netherlands' statistical publications report production for sale as follows in thousand short tons: 1976—1,768; 1977—1,962; 1978—1,917; 1979 (estimate based on 6 months' data)—2,225.

[3] Data are for years beginning April 1 of that stated.

TECHNOLOGY

The escalation of feedstock and fuel costs has hastened the development of more efficient ammonia production processes. Retrofit units that improve plant operation are based on better hydrocarbon conversion for ammonia synthesis or recovery of useful components in the synthesis loop purge stream.[77]

The Indianapolis Center for Advanced Research claimed that ammonia production yields can be increased by 20% with a new catalyst enhancement process. The technique consists of vapor deposition of sodium, sodium carbonate, or sodium hydride on commercial iron-based ammonia catalysts under controlled concentrations, temperature, and pressure, to avoid decreasing active surface area or clogging catalyst pores.[78]

PFR Engineering Systems, Inc., is designing a solar-powered primary reformer for an ammonia plant of Valley Nitrogen Producers, Inc. A field of heliostats will generate enough heat to raise the temperature of preheated process gas in the reformer by 400° F.[79]

Monsanto Co. has adapted hollow-fiber technology, previously used in reverse osmosis water purification, to the separation of hydrogen from process or waste gas streams. The system, composed of gas-permeable polysulfone hollow fibers with a proprietary coating, is reportedly more energy efficient than molecular sieve or cryogenic techniques.[80]

Linde AG has developed a cryogenic process for the recovery of argon from ammonia synthesis loop purge gas. About 14 tons of argon can be obtained daily from a 1,000-ton-per-day ammonia plant.[81]

The Tennessee Valley Authority (TVA) conducted an ammonia-from-coal symposium in May 1979. Discussion topics included future feedstock availability, coal-gasification process technology, operating experiences, and TVA's own retrofit plant.[82]

The Charles F. Kettering Research Laboratory has developed a small-scale fertilizer generator that utilizes electric arc technology to produce nitric acid, which is reacted with limestone to produce calcium nitrate, or with phosphate rock to yield a mixed nitrogen and phosphorus fertilizer.[83]

A joint United States - United Kingdom study sponsored by government and private industry was initiated to investigate the hazards involved in the transportation and storage of ammonia, particularly to determine the dispersion of ammonia spills on land and water.[84]

A process developed by the U.S. Department of Agriculture and approved by EPA uses ammonia to prevent air-dried feed corn from spoiling. Ammonia is introduced into the air flowing through feed corn in drying bins, thus suppressing the growth of microorganisms and saving energy required by high-temperature drying.[85] Other recent developments in ammonia end uses include fracturing some forms of oil shale with high organic content,[86] and imparting satisfactory permanent-press characteristics to all-cotton fabrics.[87] In addition, urea crystals have been used to efficiently convert laser-generated visible light to shorter wavelength ultraviolet light at room temperature.[88]

The "cold-flo converter," a new device for direct application of ammonia fertilizer, uses adiabatic expansion to cool pressurized liquid ammonia from ambient temperature to the normal boiling point, and discharge it into the soil at atmospheric pressure.[89]

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Peat

By Richard H. Singleton and James P. Searls[1]

U.S. peat production increased 5% in 1978 to about 822,000 tons but stayed essentially level in 1979 at about 825,000 tons.[2] There were 100 active peat operations in 1978 and 97 in 1979. Producers' stocks, first reported in 1978, were 394,000 tons in 1978 and 350,000 tons in 1979. Michigan was the highest peat-producing State, with about 28% of total peat production in 1978 and 31% of total production in 1979. Michigan's peat production declined 13% in 1978 but increased 17% in 1979. Michigan, Florida, Illinois, Indiana, and New York were, in that order, the top peat-producing States and, combined, accounted for 76% of U.S. production in 1978 and 77% in 1979. Reed-sedge peat was 57% of total peat production in 1978 and 59% in 1979. Other peat types produced in 1978 were humus (24%), hypnum moss (5%), sphagnum moss (2%), and other unclassified types of peat (13%). Other peat types produced in 1979 were humus (23%), hypnum moss (3%), sphagnum moss (2%), and other unclassified types of peat (13%).

Domestic peat sales by domestic producers increased 3% to 750,000 tons in 1978 and 6% to 798,000 tons in 1979. About 56% of domestic peat sold in 1978 was packaged, and about 57% in 1979 was packaged. General soil improvement, potting soils, and nursery applications accounted for 59%, 19%, and 9%, respectively, in 1978, and 49%, 26%, and 8%, respectively, in 1979. The average apparent 1978 peat price was $17.32 per ton f.o.b. mine, an insignificant change from that of 1977. The average apparent 1979 price was $19.44 per ton f.o.b. mine, a 12% increase from that of 1978. In 1978, the decrease in packaged peat prices were offset by the increase in bulk price. In 1979, both packaged and bulk prices increased.

Peat imports, 97% of which were premium-grade sphagnum moss peat from Canada, increased 15% to 0.38 million tons in 1978 and stayed at this level in 1979. Apparent consumption of peat increased 7% to 1.13 million tons in 1978 and another 4% to 1.18 million tons in 1979. Imports contributed about 34% of apparent consumption tonnage and 74% of apparent consumption in 1978. In 1979, imports contributed about 32% of apparent consumption tonnage,

Table 1.—Salient peat statistics

	1976	1977	1978	1979
United States:				
Number of active operations	102	102	100	97
Production thousand short tons	774	781	822	825
Sales by producers do	731	726	750	798
Bulk do	272	325	328	324
Packaged do	459	401	422	474
Value of sales thousands	$12,079	$12,520	$12,988	$15,517
Average per ton	16.52	17.25	17.32	19.44
Average per ton—bulk	14.00	12.22	13.98	15.05
Average per ton—packaged or baled	18.02	21.32	19.92	22.46
Imports thousand short tons	338	330	380	381
Apparent consumption[1] do	1,069	1,056	1,130	1,179
Yearend producers' stocks do	NA	NA	394	350
World: Production do	228,000	[r]228,000	224,000	222,000

[r]Revised. NA Not available.
[1]Sales plus imports.

and 72% of apparent consumption value.

Estimated world production was approximately 224 million tons for 1978 and 1979. About 95% was produced in the U.S.S.R. Other significant producers were Ireland, the Federal Republic of Germany, and Finland.

DOMESTIC PRODUCTION

Peat was produced in 100 separate U.S. operations in 1978, and two idle producers shipped from stock. There were 97 producers in the United States in 1979, with three idle producers shipping from stock. Approximately 48% of U.S. production in 1978 was from nine large mines with annual capacities greater than 25,000 tons. These included four reed-sedge mines, located in Michigan; one reed-sedge mine in each of the States of Florida, Illinois, and Indiana; one humus mine in New York; and a mine producing humus and other unclassified peat in Florida.

In 1979, there were eight large mines with annual capacities over 25,000 tons furnishing 49% of U.S. production. These included three reed-sedge mines in Michigan, one reed-sedge mine in each State of Florida and Indianh, one humus mine in New York, one mine producing reed-sedge and humus in Illinois, and one mine producing humus and other unclassified peat in Florida.

Reed-sedge production increased 10% and was 57% of U.S. total peat production in 1978. Reed-sedge production increased 5% in 1979 and was 59% of U.S. total peat production. Humus production increased 18% in 1978 and was 24% of the U.S. total peat production. Humus production declined 2% in 1979 and was 23% of U.S. total peat production.

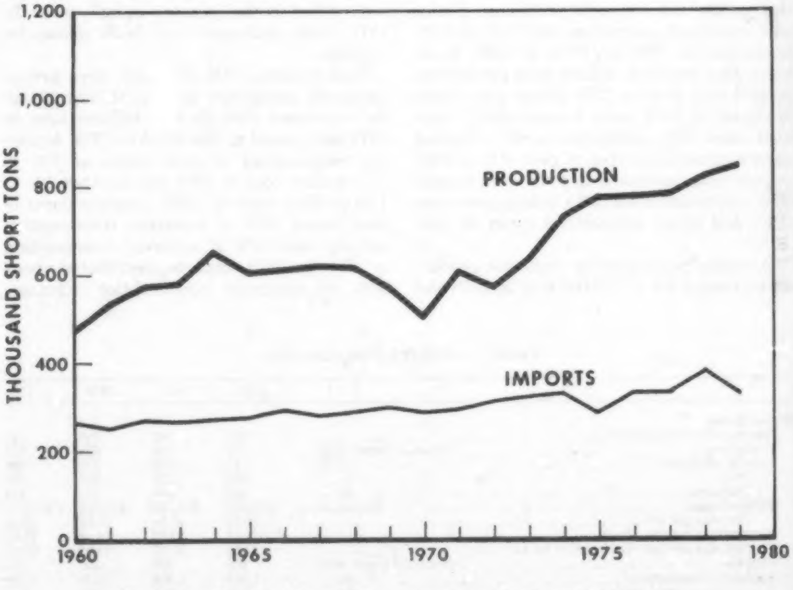

Figure 1.—Production and imports of peat in the United States.

Table 2.—U.S. peat production and yearend producers' stocks, by kind and State

(Thousand short tons)

State	Active plants	Sphagnum moss		Hypnum moss		Reed-sedge		Humus		Other		Total[1]	
		Production	Yearend stocks	Production	Yearend stocks	Production	Yearend stocks	Production	Yearend stocks	Production	Yearend stocks	Production	Yearend stocks
1978													
Colorado	6	--	--	--	--	W	W	--	--	27	([2])	34	6
Florida	11	--	--	W	--	107	18	14	2	W	W	173	34
Illinois	4	--	--	W	--	W	--	W	W	--	--	86	W
Indiana	9	--	--	--	--	W	W	W	--	11	2	75	43
Iowa	4	--	--	W	([2])	W	14	1	1	--	--	5	15
Maine	3	W	W	--	--	W	--	W	--	--	--	8	W
Maryland	1	--	--	--	--	2	1	1	([2])	--	--	3	1
Michigan	16	3	--	--	--	201	223	W	7	W	--	238	230
Minnesota	3	W	W	--	--	W	W	--	--	--	--	18	14
New Jersey	6	--	--	--	--	W	W	W	W	--	--	29	8
New York	6	--	--	--	--	7	([2])	32	([2])	11	11	50	11
Ohio	6	([2])	([2])	--	--	--	--	12	5	--	--	13	5
Pennsylvania	9	--	--	--	--	5	3	22	1	--	--	27	4
South Carolina	1	--	--	--	--	--	--	16	--	--	--	16	--
Washington	4	--	--	--	--	W	--	W	--	5	5	10	5
Wisconsin	3	--	--	--	--	--	--	W	--	W	--	12	--
Other States[3]	8	11	6	38	8	142	64	99	9	54	14	25	18
Total[1]	100	14	6	38	8	465	323	197	25	108	32	822	394

See footnotes at end of table.

Table 2.—U.S. peat production and yearend producers' stocks, by kind and State —Continued

(Thousand short tons)

State	Active plants	Sphagnum moss		Hypnum moss		Reed-sedge		Humus		Other		Total[1]	
		Production	Yearend stocks	Production	Yearend stocks	Production	Yearend stocks	Production	Yearend stocks	Production	Yearend stocks	Production	Yearend stocks
1979													
Colorado	6	--	--	--	--	W	W	--	--	W	W	33	W
Florida	9	--	--	--	--	106	W	15	W	46	W	167	16
Illinois	5	--	--	W	--	W	--	W	W	W	--	87	W
Indiana	10	--	--	--	--	53	W	19	W	13	W	84	64
Iowa	4	--	--	W	--	W	W	1	1	--	--	7	W
Maine	3	3	W	--	--	W	--	W	--	--	--	3	W
Maryland	1	--	--	--	--	2	([2])	1	--	--	--	3	([2])
Massachusetts	1	--	--	--	--	2	--	--	--	--	--	2	--
Michigan	16	W	W	--	--	222	185	25	W	W	--	256	186
Minnesota	3	W	W	--	--	W	W	--	--	--	--	28	W
New Jersey	6	--	--	--	--	W	W	W	W	--	--	21	6
New Mexico	1	--	--	--	--	--	--	2	--	--	--	2	--
New York	6	--	--	--	--	7	W	33	W	--	W	40	14
Ohio	6	([2])	([2])	--	--	5	5	4	4	--	--	10	9
Pennsylvania	8	--	--	--	--	6	2	20	([2])	--	--	26	2
Washington	3	--	--	--	--	--	--	W	W	W	W	11	W
Wisconsin	3	--	--	--	--	--	--	W	--	W	W	11	W
Other States[4]	6	11	11	26	7	85	89	73	18	46	28	34	53
Total[1]	97	14	11	26	7	487	281	193	24	105	27	825	350

W Withheld to avoid disclosing company proprietary data; included with "Other States."

[1] Data may not add to totals shown because of independent rounding.

[2] Less than 1/2 unit.

[3] Includes California, Georgia, Massachusetts, Montana, New Mexico, North Dakota, and data indicated by symbol W.

[4] Includes California, Georgia, Montana, South Carolina, and data indicated by symbol W.

Table 3.—Relative size of peat operations in the United States

Size in tons per year	Number of active plants		Production (thousand tons)	
	1978	1979	1978	1979
25,000 and over	9	8	398	406
15,000 to 24,999	9	8	173	160
10,000 to 14,999	6	6	69	75
5,000 to 9,999	12	15	77	96
2,000 to 4,999	20	17	69	55
1,000 to 1,999	18	14	26	22
Under 1,000	26	29	10	11
Total	100	97	822	825

CONSUMPTION AND USES

Domestic sales by domestic peat producers in 1978 increased 3% to 750,000 tons and another 6% to 798,000 tons in 1979. There was an increasing trend of sales in package form. The percentage was up 5% to 56% of sales in 1978 and up 12% to 57% of sales in 1979. Bulk sales remained level. The percentage of each peat type that was packaged in 1978 was sphagnum moss, 96%; hypnum moss, 74%; humus, 64%; reed-sedge, 60%; and unclassified peat, 5%. The percentage of each peat type that was packaged in 1979 was sphagnum moss, 93%; hypnum moss, 88%; humus, 57%; reed-sedge, 69%; and other unclassified peat, 3%.

Domestic peat sales by domestic producers for soil improvement steadily decreased. Sales declined from 72% in 1977 to 59% in 1978 and 49% in 1979. Potting soil sales increased from 18% in 1977 to 19% in 1978 and 26% in 1979.

Apparent consumption of peat increased 7% in 1978 to 1.13 million tons and 4% in 1979 to 1.18 million tons. In 1978, about 34% was imported; in 1979, about 32% was imported. The end use pattern of imported peat, mostly sphagnum moss from Canada, was not known. Imported sphagnum moss peat has more desirable qualities than the domestically produced peat for many purposes. There were small quantities of sphagnum moss, similar to Canadian sphagnum moss, mined in Maine, Michigan, Minnesota, and Ohio.

Table 4.—Ranking of States, by peat sales

State	Quantity (short tons)	Value (thousands)
1978		
Michigan	219,900	$3,850
Florida	157,700	2,250
Illinois	84,300	1,590
Indiana	57,200	789
New York	49,500	770
Colorado	29,900	188
New Jersey	24,300	568
Pennsylvania	22,900	435
Minnesota	20,500	716
1979		
Michigan	257,800	4,847
Florida	153,400	2,190
Illinois	85,500	1,610
Indiana	76,500	1,242
New York	37,800	630
Colorado	33,000	299
Pennsylvania	24,300	531
New Jersey	22,700	549
Minnesota	21,100	827

Table 5.—U.S. peat sales by

Use	Sphagnum moss			Hypnum moss		
	Quantity			Quantity		
	Weight (short tons)	Volume[1] (cubic yards)	Value (thousands)	Weight (short tons)	Volume (cubic yards)	Value (thousands)
1978						
Earthworm culture medium	140	550	$4	12,300	31,600	$400
General soil improvement	3,700	26,000	300	16,500	41,000	400
Golf course	--	--	--	--	--	--
Ingredient for potting soils	130	960	3	2,200	5,100	30
Mixed fertilizers	190	1,000	3	--	--	--
Mushroom beds	1,000	7,400	90	--	--	--
Nursery	230	1,250	4	600	1,500	20
Packing flowers, plants, shrubs, etc	--	--	--	1,900	4,000	20
Seed inoculant	90	500	2	--	--	--
Vegetable growing	--	--	--	--	--	--
Other	3,300	16,860	190	1,400	2,900	30
Total[2]	8,700	54,500	570	35,000	86,200	1,000
1979						
Earthworm culture medium	100	500	4	9,300	24,800	524
General soil improvement	4,700	36,200	408	15,800	39,600	436
Golf course	400	2,200	16	--	--	--
Ingredient for potting soils	200	2,400	18	1,400	3,400	16
Mixed fertilizers	100	1,200	9	--	--	--
Mushroom beds	1,300	11,200	112	--	--	--
Nursery	600	5,200	39	400	1,000	17
Packing flowers, plants, shrubs, etc	100	1,200	9	--	--	--
Seed inoculant	100	1,200	9	--	--	--
Vegetable growing	200	2,400	18	--	--	--
Other	600	4,700	57	1,400	2,800	33
Total[2]	8,600	68,600	701	28,300	71,700	1,026

[1] Volume of nearly all sphagnum moss was measured after compaction and packaging.

[2] Data may not add to totals shown because of independent rounding.

producers, by use and kind

Reed-sedge			Humus			Other (unknown)			Total [2]		
Quantity			Quantity			Quantity			Quantity		
Weight (short tons)	Volume (cubic yards)	Value (thousands)	Weight (short tons)	Volume (cubic yards)	Value (thousands)	Weight (short tons)	Volume (cubic yards)	Value (thousands)	Weight (short tons)	Volume (cubic yards)	Value (thousands)
1,000	2,600	$20	2,400	5,300	$40	290	600	$3	16,150	40,700	$500
258,500	635,000	4,070	149,000	284,500	2,660	14,000	32,600	180	442,000	1,019,000	7,600
9,200	22,200	190	9,600	18,100	130	1,000	1,600	7	19,800	42,000	300
70,400	185,000	1,200	28,200	51,200	480	45,200	96,000	560	146,000	338,000	2,300
50	200	2	5,300	9,800	100	15,400	25,600	80	20,900	36,500	200
6,100	17,300	90	3,600	7,600	60	4,100	8,230	60	14,900	40,500	300
54,750	128,000	980	9,800	17,400	100	830	1,400	5	66,000	150,000	1,100
100	300	6	2,900	5,900	30	540	1,200	6	5,400	11,400	60
--	--	--	3,300	4,400	100	--	--	--	3,400	4,930	100
2,200	5,500	60	1,760	3,200	20	540	1,200	6	4,500	9,840	90
--	--	--	3,400	6,900	100	2,500	6,300	50	10,700	32,900	375
402,300	995,000	6,700	219,300	414,000	3,800	84,400	175,000	950	749,700	1,725,000	12,968
200	800	9	2,400	4,600	32	400	800	4	12,500	31,300	573
276,900	624,000	4,926	73,500	138,400	1,129	25,800	52,700	296	396,700	890,900	7,195
13,000	29,800	271	8,000	14,800	117	1,200	2,000	13	22,600	48,900	417
129,400	368,500	2,376	40,200	69,000	657	40,000	86,000	512	211,200	469,400	3,580
2,000	4,500	48	4,500	8,200	105	12,000	20,000	80	18,600	33,900	242
8,200	17,900	137	3,600	7,600	63	--	--	--	13,200	36,700	313
51,000	115,400	1,017	9,200	19,700	156	6,000	11,100	80	67,100	152,500	1,309
1,900	4,200	45	23,300	43,900	387	--	--	--	25,400	49,400	442
--	--	--	5,100	6,800	773	--	--	--	5,200	8,100	782
3,200	8,400	100	1,900	2,500	19	900	1,500	5	6,200	15,900	143
4,500	11,000	120	6,700	15,700	214	6,000	13,000	97	19,300	47,100	521
490,300	1,124,600	9,049	178,600	332,300	3,653	92,200	187,000	1,088	798,000	1,784,100	15,517

Table 6.—U.S. peat sales by producers, by use

Use	In bulk: Quantity (short tons)	In bulk: Value (thousands)	In packages: Quantity (short tons)	In packages: Value (thousands)	Total: Quantity (short tons)	Total: Value (thousands)
1978						
Earthworm culture medium	6,000	$82	10,100	$415	16,150	$497
General soil improvement	132,900	1,850	308,800	5,780	441,700	7,630
Golf course	18,300	302	1,440	22	19,800	324
Ingredient for potting soils	76,800	1,010	69,200	1,290	146,100	2,300
Mixed fertilizers	16,600	137	4,300	66	20,900	203
Mushroom beds	9,500	120	5,400	180	14,900	300
Nursery	57,300	957	8,900	148	66,200	1,100
Packing flowers, plants, shrubs, etc	5,400	61	32	1	5,400	62
Seed inoculant	330	3	3,100	105	3,400	108
Vegetable growing	3,400	33	1,070	52	4,500	85
Other	1,050	17	9,600	358	10,700	375
Total[1]	327,600	4,580	422,100	8,409	749,700	12,988
1979						
Earthworm culture medium	3,200	52	9,300	522	12,500	573
General soil improvement	113,200	1,667	283,500	5,529	396,700	7,196
Golf course	20,700	378	1,900	39	22,600	417
Ingredient for potting soils	96,300	1,254	114,900	2,325	211,200	3,580
Mixed fertilizers	13,500	145	5,100	98	18,600	242
Mushroom beds	9,300	151	3,800	162	13,200	313
Nursery	57,400	1,064	9,700	245	67,100	1,309
Packing flowers, plants, shrubs, etc	2,900	29	22,500	413	25,400	442
Seed inoculant	300	45	5,000	737	5,200	782
Vegetable growing	3,100	33	3,100	110	6,200	143
Other	4,500	64	14,800	457	19,300	521
Total[1]	324,400	4,881	473,600	10,637	798,000	15,517

[1] Data may not add to totals shown because of independent rounding.

Table 7.—U.S. peat sales by producers, by State

Producing State	1978: Quantity (short tons)	1978: Value[1] (thousands)	1978: Percent packaged	1979: Quantity (short tons)	1979: Value[1] (thousands)	1979: Percent packaged
Colorado	29,900	$188	4	33,000	$299	41
Florida	157,700	2,250	22	153,400	2,190	23
Illinois	84,300	1,590	93	85,500	1,610	92
Indiana	57,200	789	42	76,500	1,242	54
Iowa	6,000	182	10	10,900	270	24
Maine	3,800	158	87	3,000	292	80
Maryland	2,900	55	12	2,800	W	10
Massachusetts	2,100	65	23	1,800	56	14
Michigan	219,900	3,850	75	257,800	4,847	90
Minnesota	20,500	716	83	21,100	827	86
New Jersey	24,300	568	51	22,700	549	42
New Mexico	2,000	60	--	2,000	40	50
New York	49,500	770	90	37,800	630	96
North Dakota	W	W	60	(2)	W	40
Ohio	10,300	90	71	7,800	191	62
Pennsylvania	22,900	435	24	24,300	531	25
South Carolina	15,500	265	82	W	W	81
Washington	9,600	124	--	10,800	148	--
Wisconsin	11,600	201	40	11,400	720	42
Other States[3]	19,600	637	98	35,200	1,165	73
Total[4]	749,700	12,988	56	798,000	15,517	59

W Withheld to avoid disclosing company proprietary data; included with "Other States."

[1] Values are f.o.b. producing plant.

[2] Less than 1/2 unit.

[3] Includes California, Georgia, Montana, and data indicated by symbol W.

[4] Data may not add to totals shown because of independent rounding.

PRICES AND SPECIFICATIONS

The average 1978 price, $17.32 per ton f.o.b. mine, for domestic peat did not change appreciably from that of 1977. Changes in average bulk prices and packaged prices essentially offset each other. In 1979, average total, average for bulk, and average for packaged prices increased as did the average customs price for imported peat.

Table 8.—Prices for peat, by type[1]

(Dollars per unit)

	Sphagnum moss	Hypnum moss	Reed-sedge	Humus	Other	Total
1978						
Domestic:						
Bulk:						
Per ton	23.89	12.29	15.71	13.96	10.67	13.98
Per cubic yard	5.96	5.59	6.77	7.35	5.18	6.49
Packaged or baled:						
Per ton	66.88	33.73	17.08	19.44	21.62	19.92
Per cubic yard	10.56	13.19	6.63	10.82	9.50	8.25
Total:						
Per ton	65.22	28.14	16.53	17.48	11.26	17.32
Per cubic yard	10.45	11.42	6.66	9.25	5.43	7.53
Imported, total, per ton[2]	98.71	XX	XX	XX	XX	98.71
1979						
Domestic:						
Bulk:						
Per ton	34.70	15.28	17.40	14.27	11.54	15.05
Per cubic yard	7.49	6.47	7.72	7.54	5.72	7.14
Packaged or baled:						
Per ton	84.70	39.20	18.94	25.21	19.76	22.46
Per cubic yard	10.33	15.35	8.19	13.73	8.14	9.66
Total:						
Per ton	81.42	36.22	18.46	20.45	11.80	19.44
Per cubic yard	10.22	14.32	8.06	10.99	5.82	8.70
Imported, total, per ton[2]	105.06	XX	XX	XX	XX	105.06

XX Not applicable.
[1] Prices are f.o.b. mine.
[2] Customs price.

Table 9.—Average density of domestic peat sold

(Pounds per cubic yard)

	Sphagnum moss	Hypnum moss	Reed-sedge	Humus	Other
1978					
Bulk	500	900	860	1,050	970
Packaged	310	780	780	1,060	880
Bulk and packaged	320	810	810	1,060	960
1979					
Bulk	430	850	890	1,060	990
Packaged	240	780	860	1,090	820
Bulk and packaged	250	790	870	1,075	990

FOREIGN TRADE

Peat imports increased 18% to 380,000 tons in 1978. Total imports remained constant in 1979; 99.7% of the imports came from Canada. In 1978 and 1979, 57% of peat imports entered through New York State and New England ports. About 25% was shipped to the Midwest and about 17% was shipped to the West Coast. The Federal Republic of Germany was a significant second source in 1978 but dropped to a minor source of peat imports in 1979.

Table 10.—U.S. imports for consumption of peat moss, by grade and country

Country	Poultry- and stable-grade		Fertilizer-grade		Total	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1978						
Canada	6,645	$752	364,002	$36,148	370,647	$36,900
Finland	--	--	61	8	61	8
Germany, FederalRepublic of	740	57	8,535	521	9,275	578
Ireland	24	10	58	8	82	18
Netherlands	17	5	--	--	17	5
New Zealand	37	3	15	2	52	5
South Africa, Republic of	--	--	32	3	32	3
Sweden	--	--	26	12	26	12
Switzerland	--	--	33	2	33	2
Taiwan	63	7	--	--	63	7
United Kingdom	--	--	15	2	15	2
Yemen, People's Democratic Republic of (Aden)	--	--	7	([1])	7	([1])
Total	7,526	834	372,784	36,706	380,310	37,540
1979						
Austria	24	50	--	--	24	50
Canada	7,620	1,057	371,930	38,708	379,550	39,765
China, Mainland	56	1	--	--	56	1
Finland	--	--	3	([1])	3	([1])
France	--	--	22	2	22	2
Germany, FederalRepublic of	104	28	527	87	631	115
Ireland	51	8	--	--	51	8
Mexico	--	--	16	1	16	1
Netherlands	1	([1])	--	--	1	([1])
South Africa, Republic of	--	--	16	1	16	1
Sweden	10	4	16	8	26	12
United Kingdom	167	28	--	--	167	28
Total	8,033	1,176	372,530	38,807	380,563	39,983

[1] Less than 1/2 unit.

Table 11.—U.S. imports for consumption of peat moss, by grade and customs district

Customs district	Poultry- and stable-grade		Fertilizer-grade		Total	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1978						
Baltimore, Md	--	--	93	$14	93	$14
Boston, Mass	--	--	116	8	116	8
Buffalo, N.Y	551	$30	35,288	4,062	35,839	4,092
Charleston, S.C	--	--	34	2	34	2
Detroit, Mich	1,608	138	51,199	5,584	52,807	5,722
Duluth, Minn	--	--	5,691	690	5,691	690
Great Falls, Mont	73	4	36,071	3,790	36,144	3,794
Honolulu, Hawaii	37	3	10	1	47	4
Houston, Tex	74	4	361	42	435	46
Los Angeles, Calif	613	46	2,924	88	3,537	134
Milwaukee, Wis	--	--	4	([1])	4	([1])
Mobile, Ala	--	--	1,433	101	1,433	101
New Orleans, La	36	4	560	47	596	51
New York, N.Y	270	34	327	19	597	53
Norfolk, Va	1	([1])	97	8	98	8
Ogdensburg, N.Y	58	4	117,936	11,025	117,994	11,029
Pembina, N. Dak	612	61	29,872	2,884	30,484	2,945
Philadelphia, Pa	--	--	33	2	33	2
Portland, Maine	2,698	423	34,484	3,558	37,182	3,981
Portland, Oreg	124	12	29	3	153	15
Providence, R.I	11	1	--	--	11	1
St. Albans, Vt	106	10	26,225	2,399	26,331	2,409
San Francisco, Calif	104	11	300	37	404	48
San Juan, P.R	39	3	1,534	117	1,573	120
Seattle, Wash	342	34	26,920	2,126	27,262	2,160
Tampa, Fla	--	--	1,243	99	1,243	99
Wilmington, N.C	169	12	--	--	169	12
Total	7,526	834	372,784	36,706	380,310	37,540
1979						
Buffalo, N. Y	128	11	33,827	4,359	33,955	4,370
Charleston, S. C	--	--	17	2	17	2
Detroit, Mich	1,566	155	56,077	6,546	57,643	6,701
Duluth, Minn	27	2	6,669	964	6,696	966
Great Falls, Mont	81	7	31,576	3,626	31,657	3,633
Honolulu, Hawaii	24	4	--	--	24	4
Laredo, Tex	--	--	15	3	15	3
Los Angeles, Calif	522	85	400	71	922	156
Milwaukee, Wis	1	([1])	--	--	1	([1])
Mobile, Ala	--	--	15	2	15	2
New Orleans, La	--	--	76	15	76	15
New York, N. Y	32	56	--	--	32	56
Norfolk, Va	1	([1])	--	--	1	([1])
Ogdensburg, N. Y	--	--	125,694	11,276	125,694	11,276
Pembina, N. Dak	953	93	30,176	3,659	31,129	3,752
Philadelphia, Pa	18	2	--	--	18	2
Portland, Maine	4,167	714	28,035	2,776	32,202	3,490
Portland, Oreg	2	2	--	--	2	2
Providence, R. I	43	2	--	--	43	2
St. Albans, Vt	156	6	25,033	2,339	25,189	2,345
San Francisco, Calif	9	4	385	53	394	57
Seattle, Wash	303	33	34,500	3,111	34,803	3,144
Tampa, Fla	--	--	35	5	35	5
Total	8,033	1,176	372,530	38,807	380,563	39,983

[1] Less than 1/2 unit.

Table 12.—Peat moss imported for consumption from Canada and the Federal Republic of Germany, by grade and customs district

Customs district	Canada				Federal Republic of Germany			
	Poultry- and stable-grade		Fertilizer-grade		Poultry- and stable-grade		Fertilizer-grade	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1978								
Baltimore, Md	--	--	--	--	--	--	79	$8
Boston, Mass	--	--	--	--	--	--	116	8
Buffalo, N.Y	551	$30	35,288	$4,062	--	--	--	--
Charleston, S.C	--	--	--	--	--	--	84	2
Detroit, Mich	1,608	138	51,181	5,583	--	--	--	--
Duluth, Minn	--	--	5,691	690	--	--	--	--
Great Falls, Mont	73	4	36,071	3,790	--	--	--	--
Houston, Tex	--	--	--	--	74	$4	348	35
Los Angeles, Calif	567	42	171	12	45	2	2,714	73
Milwaukee, Wis	--	--	4	([1])	--	--	--	--
Mobile, Ala	--	--	--	--	--	--	1,433	101
New Orleans, La	--	--	15	1	36	4	545	46
New York, N.Y	--	--	--	--	180	14	327	19
Norfolk, Va	--	--	--	--	--	--	97	8
Ogdensburg, N.Y	58	4	117,914	11,022	--	--	--	--
Pembina, N. Dak	612	61	29,872	2,884	--	--	--	--
Portland, Maine	2,698	423	34,462	3,555	--	--	--	--
Portland, Oreg	--	--	--	--	123	12	29	3
St. Albans, Vt	106	10	26,173	2,393	--	--	--	--
San Francisco, Calif	30	5	255	32	74	6	45	5
San Juan, P.R	--	--	--	--	39	3	1,510	112
Seattle, Wash	342	35	26,905	2,124	--	--	15	2
Tampa, Fla	--	--	--	--	--	--	1,243	99
Wilmington, N.C	--	--	--	--	169	12	--	--
Total	6,645	752	364,002	36,148	740	57	8,535	521
1979								
Buffalo, N. Y	128	11	33,824	4,359	--	--	--	--
Charleston, S. C	--	--	--	--	--	--	17	2
Detroit, Mich	1,566	155	56,077	6,547	--	--	--	--
Duluth, Minn	27	2	6,669	964	--	--	--	--
Great Falls, Mont	81	7	31,576	3,626	--	--	--	--
Honolulu, Hawaii	24	4	--	--	--	--	--	--
Laredo, Tex	--	--	15	3	--	--	--	--
Los Angeles, Calif	271	33	--	--	84	24	400	71
Mobile, Ala	--	--	--	--	--	--	15	2
New Orleans, La	--	--	--	--	--	--	60	7
Ogdensburg, N. Y	--	--	125,694	11,276	--	--	--	--
Pembina, N. Dak	953	93	30,176	3,659	--	--	--	--
Philadelphia, Pa	--	--	--	--	18	2	--	--
Portland, Maine	4,167	714	28,035	2,776	--	--	--	--
Portland, Oreg	--	--	--	--	2	2	--	--
St. Albans, Vt	156	6	24,979	2,334	--	--	--	--
San Francisco, Calif	--	--	385	53	--	--	--	--
Seattle, Wash	247	32	34,500	3,111	--	--	--	--
Tampa, Fla	--	--	--	--	--	--	35	5
Total	7,620	1,057	371,930	38,708	104	28	527	87

[1] Less than 1/2 unit.

WORLD REVIEW

World production remained at approximately 220 million short tons in both 1978 and 1979. About 95% of this total was produced in the U.S.S.R. Other significant producers were Ireland, the Federal Republic of Germany, Finland, and the United States, in decreasing order of production.

Burundi.—Plans were announced in 1978 to develop a number of peat bogs to meet the country's energy needs. Peat reserves were estimated to be about 500 million tons.

Canada.—Peat production, mainly sphagnum moss for agricultural use, increased 11% in 1978 to 480,000 tons. The value of peat production increased 32% to Can$35.2 million. Canadian peat production pattern, by Province, was Quebec, 43%; New Brunswick, 27%; Alberta, 10%; Manitoba, 8%; and British Columbia, 5%. Smaller tonnages were produced in Nova Scotia, Ontario, and Saskatchewan. About 77% of Canada's 1978 production was exported to the United States. In 1979, Canadian peat production declined by 6% to 450,800 tons. Total value of production declined by 4% to Can$33.8 million. Provincial production percentages were Quebec, 44%; New Brunswick, 29%; Manitoba, 8%; Alberta, 7%; and British Columbia, 6%. Nova Scotia, Ontario, and Saskatchewan produced smaller tonnages. About 84% of Canada's 1979 production was exported to the United States.

Finland.—Production of fuel peat increased nearly 50% in 1978 to 2.1 million tons. This was a twentyfold increase over that of 1970. Of current production, 95% was milled peat and the remainder was sod peat. The latter was used in small boilers for electrical power generation and in production of peat metallurgical coke. A small fraction of the milled peat was used to manufacture peat briquets for burning in small boilers and home heating furnaces. Sixty-nine peat-burning energy facilities, mostly state-owned, operated in 1978 and generated electrical power and heat for municipalities. About 2% to 3% of Finland's energy requirements were met by burning peat.

In addition to fuel peat, about 300,000 tons of milled peat was produced for horticultural use. Total peat production was 2.4 million tons in 1978. The peat production target for 1990 is 7.3 million tons or 20 million cubic meters.

Ireland.—Production of fuel peat was 5.08 and 4.04 million tons in 1978 and 1979, respectively, continuing a declining production trend. Production of milled peat, a component of fuel peat, also declined from 3.4 million tons in 1977 to 2.9 million tons in 1978 and to 2.2 million tons in 1979. The balance of the fuel peat was sod peat. Milled peat production doubled during the 1973-76 period and has declined since that time. Sod peat production has remained relatively constant during the 1977-78 period at 2.2 million tons. In 1979, sod peat production declined to 1.8 million tons. Moss peat production for horticultural purposes was 92,000 tons in 1977, 91,000 tons in 1978, and 101,000 tons in 1979.

U.S.S.R.—The Soviet Union continued to produce over 90% of the world's peat, more than 200 million tons per year. Of this total, about 60% was produced in the Russian Soviet Federated Socialist Republic and 20% in Byelorussia. More than half of the U.S.S.R.'s production came from collective farms. About two-thirds of the country's peat was consumed in agriculture, and the balance was used as fuel. Peat-fueled electrical generating capacity was about 5,000 megawatts; that included some 600-megawatt units. Approximately 100,000 tons was exported to market economy countries. Total estimated reserves were about 180 billion tons.

Table 13.—Peat: World production, by country

(Thousand short tons)

Country[1]	1976	1977	1978[p]	1979[e]
Argentina	11	7	4	4
Australia	[r]5	6	7	7
Canada, agricultural use	435	426	480	[2]451
Denmark, agricultural use[3]	43	44	52	50
Finland:				
Agricultural use	[r]218	255	224	230
Fuel	[r]397	661	2,061	1,500
France, agricultural use	[r]155	[r][e]155	155	155
Germany, Federal Republic of:				
Agricultural use	[r]1,881	2,107	2,257	2,300
Fuel	[r]250	244	251	275
Hungary, agricultural use[e]	80	80	80	80
Ireland:				
Agricultural use	78	[r]91	91	101
Fuel	[r]6,564	6,009	5,167	4,143
Israel, agricultural use[e]	22	22	22	20
Japan[e]	[r]80	[r]80	65	65
Korea, Republic of, agricultural use[e]	4	--	--	--
Netherlands[e]	450	450	450	450
Norway:				
Agricultural use[e]	66	66	66	80
Fuel[e]	1	1	1	1
Poland:				
Agricultural use[e]	40	40	40	40
Fuel[e]	[r]2	[r]2	2	2
Spain	[r]34	46	[e]45	45
Sweden:				
Agricultural use	98	102	[e]105	105
Fuel	35	33	[e]33	33
U.S.S.R.:				
Agricultural use	145,000	[r][e]145,000	[e]145,000	145,000
Fuel[e]	66,000	66,000	66,000	66,000
United States, agricultural use	969	781	822	[2]825
Total	[r]223,018	223,208	223,980	222,462
Fuel peat included in total	[r]73,249	72,950	73,515	71,954

[e]Estimate. [p]Preliminary. [r]Revised.

[1] In addition to the countries listed, Austria, Iceland, and Italy produce negligible quantities of fuel peat, and the German Democratic Republic is a major producer, but output is not officially reported and available information is inadequate for formulation of reliable estimates of output levels.

[2] Reported figure.

[3] Sales.

TECHNOLOGY

The Institute of Gas Technology began a broad-based program to study the gasification of peat under a new $4.5 million contract with the U.S. Department of Energy. The program was to include experimentation on peat harvesting, dewatering, and gasification. The contract covered environmental and socioeconomic studies and peat resource estimations.

The Minnesota Gas Co. applied to the State of Minnesota for a 25-year lease on a 200,000-acre tract of peat land in north-central Minnesota. The intent was to build three peat gasification plants capable of producing a total of 250 million cubic feet per day of synthetic natural gas. The proposed peat mining raised a controversial environmental issue in the State of Minnesota. Single-pass peat harvesting will disturb only about 5% as much land per year as would harvesting in thin layers by the milling method. It is recognized that single-pass harvesting using a hydraulic dredge, would require a rapid and weather-resistant dewatering system. The U.S. Bureau of Mines began an experimental study of the effects of peat mining on the area's hydrology and water quality.

First Colony Farms, Inc., continued to develop peat mining techniques on its properties in eastern North Carolina. The U.S. Air Force succeeded, after condemnation proceedings, to restrict a 70-square-mile area of this property to bombing practice. However, First Colony Farms reported that it had sufficient peat reserves to power four 150-megawatt powerplants for about 50 years. Mining experiments in 1978 using Finnish and Russian equipment indicated that the thin-layer milling method was not feasible. Excessive dusting and cypress roots left below the surface after logging near the turn of the century caused problems. Experimental mining with a cutting wheel to produce an extruded shape that could be air-dried in the field was successful. It appeared that heavier equipment than used experimentally would be required to reduce maintenance in a commercial operation. First Colony Farms obtained a permit from the State of North Carolina to mine a 219-acre tract over a 2-year period. After 4 to 5 feet of peat was removed, an agricultural crop was to be planted.

In 1979, First Colony Farms finished its experiments with harvesting equipment. Small shipments of peat were sent to a brick plant and an electric utility company for experimental mixing with coal as fuel. An experimental 1-acre area was mined and successfully reclaimed for farmland. The company is working on a 200-acre test plot and have permission to develop a 1,500-acre site. The State is unsure of the environmental impact, therefore mining was permitted and the State is closely monitoring the mining.

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[1] Physical scientist, Section of Nonmetallic Minerals.

[2] Short tons are used in the text unless otherwise stated.

Perlite

By A. C. Meisinger[1]

U.S. production of processed perlite sold and used by producers in 1979 set an alltime high in quantity and value. Output was 660,000 tons and $16.4 million compared with 641,000 tons and $13.7 million in 1978.

Crude ore mined by 10 companies from 12 operations in 7 Western States in 1979 was 10% less than the record quantity of 939,000 tons mined in 1978. New Mexico operations accounted for 88% of the total mined ore in 1979, compared with 86% in 1978, and 89% in 1977.

Processed perlite was expanded in 79 plants in 33 States in 1979, and that sold and used by expanders declined 5,000 tons from the record total of 546,000 tons from 80 plants in 1978. Value of expanded perlite sold and used was a new record high of $69.1 million, an increase of 7% over the previous record value of $64.3 million set in 1978. Illinois maintained its leadership in 1979 in production and value of expanded perlite by States.

U.S. consumption of expanded perlite in building construction products in 1979 accounted for approximately 67% of the total perlite market in quantity and 63% in value, compared with 70% and 66%, respectively in 1978.

The weighted average price of processed perlite sold and used in 1979 increased 16% from $21.44 per ton in 1978. The average value of expanded perlite products sold and used in 1979 increased to nearly $128 per ton, or an increase of $10 per ton over that reported in 1978. Producers attributed the increases primarily to the higher costs of fuel and transportation during 1979.

World production of crude and/or processed perlite in 1979 (table 4), increased about 2% from 1.54 million tons in 1978 to an estimated 1.57 million tons.

Table 1.—Perlite mined, processed, expanded, and sold and used by producers in the United States

(Thousand short tons and thousand dollars)

Year	Perlite mined[1]	Processed perlite					Expanded perlite		
		Sold to expanders		Used at own plant to make expanded material		Total quantity sold and used	Quantity produced	Sold and used	
		Quantity	Value	Quantity	Value			Quantity	Value
1975	706	239	3,407	273	3,874	512	401	394	34,300
1976	727	288	4,908	265	4,489	553	438	432	41,000
1977	871	298	5,514	299	5,239	597	504	498	53,600
1978	939	320	6,813	321	6,927	641	553	546	64,300
1979	847	322	7,996	338	8,439	660	547	541	69,100

[1] Crude ore mined and stockpiled for processing.

Table 2.—Expanded perlite produced and sold and used by producers in the United States

State	1977				1978				1979			
	Quantity produced (short tons)	Sold or used			Quantity produced (short tons)	Sold or used			Quantity produced (short tons)	Sold or used		
		Quantity (short tons)	Value (thousands)	Average value per ton[1]		Quantity (short tons)	Value (thousands)	Average Value per ton[1]		Quantity (short tons)	Value (thousands)	Average value per ton[1]
Arkansas	600	600	$90	$150.00	400	400	(2)	(2)	300	300	(2)	(2)
California	41,500	40,900	4,900	119.38	39,400	38,600	$5,000	$130.68	42,900	42,800	$6,000	$141.00
Florida	27,400	26,200	2,200	83.04	28,200	28,400	2,800	97.88	29,200	29,200	2,100	105.06
Illinois	(2)	(2)	(2)	(2)	76,800	76,600	(2)	(2)	66,200	64,800	11,600	179.00
Indiana	19,800	19,800	1,800	92.53	18,600	18,900	2,400	125.75	30,900	29,500	3,600	120.35
Iowa	(2)	(2)	(2)	(2)	1,100	1,100	(2)	(2)	1,200	1,200	170	138.00
Kansas	1,000	1,000	150	157.27	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
Maine	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	7,200	7,200	(2)	(2)
Maryland	(2)	(2)	(2)	(2)	--	--	--	--	--	--	--	--
Massachusetts	(2)	(2)	(2)	(2)	2,900	2,900	540	187.30	3,600	3,600	610	170.89
Minnesota	--	--	--	--	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
Missouri	5,200	5,100	700	140.06	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
Nevada	(2)	(2)	(2)	(2)	500	500	40	80.00	600	600	50	93.31
New Hampshire	(2)	(2)	(2)	(2)	100	100	(2)	(2)	(2)	(2)	(2)	(2)
New York	6,300	6,200	840	136.21	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
Ohio	12,800	13,000	1,000	77.99	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
Pennsylvania	35,300	34,900	3,500	99.29	35,800	35,700	3,800	106.38	34,400	34,300	3,900	113.31
Tennessee	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	5,900	5,900	990	167.50
Texas	35,600	34,800	3,700	106.97	43,400	42,400	4,800	112.23	41,700	41,800	5,100	122.99
West Virginia	(2)	(2)	(2)	(2)	--	--	--	--	--	--	--	--
Other States[3]	319,000	315,000	34,700	109.94	305,000	301,000	44,900	149.46	283,000	280,000	34,000	118.45
Total[4]	504,000	498,000	53,600	107.60	553,000	546,000	64,300	117.76	547,000	541,000	69,100	127.79

[1] Average value per ton based on unrounded data.
[2] Withheld to avoid disclosing company proprietary data. Included with "Other States."
[3] Includes Alabama (1978, 1979), Arkansas (value only, 1978, 1979), Colorado, Georgia, Idaho, Illinois (1977 and value only, 1978), Iowa (1977 and value only, 1978), Kansas (1977, 1978), Kentucky, Louisiana, Maine (1977, 1978, and value only, 1979), Maryland (1977), Massachusetts (1977), Michigan, Minnesota (1978, 1979), Mississippi, Missouri (1978, 1979), Nevada (1977), New Hampshire (1977 and value only 1978, 1979), New Jersey, New York (1978, 1979), North Carolina, Ohio (1978, 1979), Oregon, Tennessee (1977, 1978), Utah, Virginia, West Virginia (1977), Wisconsin, and Wyoming.
[4] Data may not add to totals shown because of independent rounding.

DOMESTIC PRODUCTION

The quantity of perlite mined for processing by 10 companies from 12 operations in 7 Western States in 1979 was 847,000 tons, or 10% less than the record quantity of 939,000 tons mined in 1978. New Mexico operations accounted for 88% of the total ore mined in 1979, compared with 86% in 1978. The remaining 12% in 1979 was mined from deposits in Arizona, Califronia, Colorado, Idaho, Nevada, and Utah.

The quantity and value of processed perlite sold and used by producers in 1979 established new records of 660,000 tons and $16.4 million, compared with the previous record output of 641,000 tons and $13.7 million in 1978.

In 1979 perlite ore producers were Filters International, Inc., near Superior, Ariz.; American Perlite Co., near Fish Springs, Calif.; Persolite Products, Inc., Custer County, Colo.; Oneida Perlite Corp., near Malad City, Idaho; Delamor Perlite Co. in Lincoln County, Nev.; U.S. Gypsum. Co. in Pershing County, Nev.; Grefco, Inc. (two mines), Johns-Manville Perlite Corp., Silbrico Corp., and U.S. Gypsum Co., in New Mexico; and the Mountain Maid Corp. mine near Fillmore, Utah.

Expanded perlite was produced in 79 plants in 33 States in 1979, compared with 80 plants in 33 States in 1978. The quantities of expanded perlite produced and sold and used in 1979 declined 6,000 tons and 5,000 tons respectively, from the 1978 record high figures of 553,000 tons produced and 546,000 tons sold and used. However, value of expanded perlite sold and used in 1979 increased for the sixth straight year to a new record of $69.1 million, or 7% greater than the 1978 value of $64.3 million.

Leading States in descending order of quantity of expanded perlite produced in 1979 were Illinois, Mississippi, Virginia, California, Texas, Colorado, Pennsylvania, Kentucky, New Jersey, Indiana, and Florida. The leading States in descending order of value of expanded perlite sold and used in 1979 were Illinois, California, Texas, New Jersey, Mississippi, Kentucky, Virginia, Pennsylvania, Indiana, Colorado, and Florida. As in previous years, Illinois continued to be the leading State in the quantity and value of expanded perlite sold and used. California had eight producing plants in 1979, followed by Texas with seven, and Indiana and Pennsylvania with six each. In 1978, California had nine producing plants and Indiana had five plants.

CONSUMPTION AND USES

Domestic consumption of expanded perlite (quantity sold and used by producers) in 1979 declined 5,000 tons from the record quantity of 546,000 tons in 1978. The principal product uses of expanded perlite in 1979, in descending order of quantity sold and used, were roof-insulation board (included with "Other" in table 3), filter aid, acoustical ceiling tile (included in formed products), concrete aggregate, horticultural aggregate, plaster aggregate, and masonry and cavity fill insulation.

Expanded perlite used in building construction products such as concrete and plaster aggregate, insulation (loose fill), insulation board, and acoustical tile in 1979 accounted for approximately 67% of the total U.S. market for expanded perlite in quantity and 63% in value in 1979, compared with 70% and 66% respectively, in 1978, and 69% and 66% respectively, in 1977.

Table 3.—Expanded perlite sold and used by producers in the United States, by use

(Short tons)

Use	1977	1978	1979
Concrete aggregate	35,600	43,900	41,500
Fillers	6,500	10,700	12,000
Filter aid	84,900	94,400	95,800
Formed products[1]	51,000	71,400	73,400
Horticultural aggregate	38,200	36,400	36,900
Low-temperature insulation	7,200	4,300	6,200
Masonry and cavity fill insulation	19,800	21,400	22,000
Plaster aggregate	27,000	22,900	23,500
Roof insulation board	W	W	W
Other[2]	226,900	241,000	229,500
Total[3]	498,000	546,000	541,000

W Withheld to avoid disclosing company proprietary data. Included with "Other."

[1] Includes acoustic tile, pipe insulation, and miscellaneous formed products.

[2] Includes roof insulation board and various unspecified industrial uses.

[3] Data may not add to totals shown because of independent rounding.

PRICES

Processed (crushed, cleaned, and sized) perlite was sold by producers to expanders in 1979 at an average price of $24.83 per ton, a 17% increase over the 1978 price of $21.29 per ton. Processed perlite used by producers in their own expanding plants in 1979 was valued at $24.97 per ton, a 16% increase over the 1978 value of $21.58 per ton. The weighted average price of processed perlite in 1979 was $24.90 per ton, compared with $21.44 per ton in 1978, and $18.01 in 1977. The higher 1979 price per ton for processed perlite primarily reflected the increase in cost for transporting perlite ore to expanding plants during the year.

The value of expanded perlite products sold and used in 1979 (table 2), increased an average of $10 per ton over that reported by expanders in 1978, and was $20 per ton higher than the 1977 average value. In 1979, the average values for expanded perlite sold or used at plants in 33 States ranged from $75 per ton to $220 per ton, compared with $65 to $214 per ton in 1978, and $60 to $228 per ton in 1977. Average prices for expanded perlite end uses in 1979 ranged from $80 per ton for formed products to $275 per ton for loose fill insulation applications.

WORLD REVIEW

World production of crude and/or processed perlite (table 4) increased to an estimated 1.57 million tons in 1979, or approximately 2% greater than the 1.54 million tons produced in 1978. The United States, the U.S.S.R., and Greece, together, accounted for 77% of the estimated world output in 1978 and again in 1979.

Greece.—Estimated mine production of perlite in Greece in 1978 was reported to be 246,000 tons, of which 148,000 tons was processed for export, compared with 163,000 tons processed for export in 1977.

Hungary.—Perlite mined from the Tokaj Mountain area deposits in northern Hungary declined in 1978, according to preliminary estimates; output was estimated to be 102,000 tons compared with 114,000 tons in 1977.

Turkey.—Perlite ore output in 1978 was 29,600 tons, a decrease of 10% from the 1977 (revised) output of 33,000 tons.

At Cumaovasi, near Izmir, the new perlite processing and expanding plants of Etibank General Management constructed in 1978, were put into commercial production in late 1979.[2] Ore for processing and expanding was to be supplied from two nearby deposits with combined proven reserves of nearly 9 million tons.

United Kingdom.—Imports of processed perlite ore in 1979 were nearly 135,000 tons, an increase of 18% over the 1978 total of 114,000 tons. Italy and Greece were the principal sources of the imported perlite in 1978 with 65,600 tons and 36,600 tons, respectively, and in 1979 with 66,400 tons and 27,300 tons, respectively. The imported ore was expanded in Great Britain, primarily for use in plaster aggregate building products.

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[1] Industry economist, Section of Nonmetallic Minerals.

[2] Industrial Minerals (London). Industrial Minerals of Turkey. No. 143, August 1979, p. 25.

Table 4.—Perlite:[1] World production, by country

(Thousand short tons)

Country[2]	1976	1977	1978[p]	1979[e]
Australia[3]	4	2	2	3
Czechoslovakia[e]	11	11	11	11
Greece	140	163	148	150
Italy[e]	105	100	100	100
Hungary[3]	106	114	102	103
Japan[e]	72	77	80	83
Mexico[3]	16	25	27	28
New Zealand[3]	2	1	1	1
Philippines	2	2	2	2
Turkey	27	33	30	30
U.S.S.R.[e]	360	380	400	400
United States (processed ore sold and used by producers)	553	597	641	660
Total	1,398	1,505	1,544	1,571

[e] Estimate. [p] Preliminary.

[1] Unless otherwise specified, figures represent processed ore output.

[2] In addition to the countries listed, Algeria, Bulgaria, the People's Republic of China, Iceland, Mozambique, the Republic of South Africa, and Yugoslavia are believed to have produced perlite during the 1976-79 period, but output data are not reported, and available information is inadequate for formulation of reliable estimates of output levels.

[3] Crude ore.

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Phosphate Rock

By W. F. Stowasser[1]

Record tonnages of 50 and 51.6 million metric tons of marketable phosphate rock were produced in the United States in 1978 and 1979, respectively. The matrix or ore was strip mined, except for that recovered from an underground mine in Montana. The ore was beneficiated or was of sufficiently high grade to use direct in either electric furnaces, wet process phosphoric acid plants, or in normal superphosphate manufacturing plants. The phosphate rock was used to produce fertilizer, animal feed supplements, and a large number of chemicals and industrial products.

During 1978, a cabinet level review of nonfuel minerals policy was initiated under the President's Domestic Policy Review System. Phosphate rock was selected as one of the minerals to be reviewed. A Minerals Review Committee considered the projected levels of supply, demand, and price; the probability of interruption of foreign or domestic supply; the causes of supply and price problems, and the projected impacts of short- and long-term supply problems on the conduct of U.S. foreign policy. The status of U.S. reserves, production capacity, and inventories on future possible supply or price problems were to be studied with economic and social consequences of these problems defined.

The General Accounting Office (GAO) issued a report "Phosphates: A Case Study of a Valuable Depleting Mineral in America" on November 30, 1979. The report discusses the problems and long lead times involved in phosphate mine development in the United States and as the richest deposits in Florida will be depleted in the next two decades, there is concern as to how new resources may be developed to meet the Nation's agricultural needs. GAO recommended that high levels of government review the impediments limiting access to

Table 1.—Salient phosphate rock statistics

(Thousand metric tons and thousand dollars)

	1975	1976	1977	1978	1979
United States:					
Mine production	170,077	154,278	166,893	173,429	185,757
Marketable production	44,276	44,662	47,256	50,037	51,611
Value	$1,122,184	$949,379	$821,657	$928,820	$1,045,655
Average per metric ton	$25.35	$21.26	$17.39	$18.56	$20.26
Sold or used by producers	42,120	40,522	47,437	48,774	53,063
Value	$1,052,995	$857,189	$829,084	$901,378	$1,063,517
Average per metric ton	$25.00	$21.15	$17.48	$18.48	$20.04
Exports[1]	11,131	9,433	13,230	12,870	14,358
P_2O_5 content	3,587	3,022	4,251	4,118	4,611
Value	$429,222	$272,823	$288,603	$297,357	$356,481
Average per metric ton	$38.56	$28.92	$21.81	$23.10	$24.83
Imports for consumption[2]	33	42	158	908	886
Value	$1,578	$2,209	$6,079	$24,379	$21,595
Average per metric ton	$47.82	$52.60	$38.47	$26.85	$24.37
Consumption, apparent[3]	31,022	31,131	34,365	36,812	39,591
World:					
Production	108,000	108,000	117,000	125,000	[e]128,000

[e] Estimated.
[1] Exports reported to the Bureau of Mines by companies.
[2] Bureau of the Census data.
[3] Measured by sold or used plus imports minus exports.

phosphate minerals, the long-range phosphate reserve position, and legislation that may be needed to ensure supply.

The Environmental Protection Agency (EPA) issued an areawide final environmental impact statement (EIS) for the central Florida phosphate industry.[3]

A task force was assembled in 1978 to draft a supplemental EIS addressing the question of mining phosphate rock in the Osceola National Forest. The supplemental EIS was issued in April 1979.

A series of reports were prepared by Zellars-Williams, Inc. (ZWI) under contract to the Bureau of Mines to develop information on phosphate rock reserves and resources. The reports were:

(1) Evaluation of the Phosphate Deposits of Florida Using the Minerals Availability System.

(2) Evaluation of the Phosphate Deposits of Georgia, North Carolina and South Carolina Using the Minerals Availability System.

(3) Evaluation of the Phosphate Deposits of Tennessee Using the Minerals Availability System.

Legislation and Government Programs.—Environmental legislation and regulatory actions are in constant flux. An overview of the status of laws and regulations and their impact on the Florida phosphate industry is intended to show the relationship to the environmental review process: The Federal laws include the Clean Air Act, the Federal Water Pollution Control Act, as amended by the Clean Water Act of 1977, the National Environmental Policy Act, the Atomic Energy Act, and other statutory controls such as the Safe Drinking Water Act, the Resource Conservation and Recovery Act, and the Surface Mining Control and Reclamation Act.

Section 109 of the Clean Air Act requires the Administrator of the Environmental Protection Agency to issue regulations establishing national ambient air quality standards. Criteria for pollutants (sulfur oxides, particulate matter, carbon monoxide, photochemical oxidants, hydrocarbons, and nitrogen oxide) were promulgated by EPA. EPA has also promulgated standards of performance for phosphate fertilizer manufacturing operations.

The national goal expressed by the Federal Water Pollution Control Act, as amended by the Clean Water Act of 1977 (commonly referred to as the "Clean Water Act"), is the elimination of the discharge of pollutants into navigable waters by 1985. Phosphate rock beneficiation plants and phosphate fertilizer manufacturing plants may discharge waste water through point sources subject to the regulation of the Clean Water Act. Section 402 establishes the "National Pollutant Discharge Elimination System" (NPDES) which provides for issuance of permits for the discharge of pollutants through point sources to navigable waters. Discharges are subject to various technology-based "effluent limitations and standards" developed by EPA and promulgated as regulations, and are generally incorporated as requirements in NPDES permits.

When a new operation starts, new sources of pollution must comply with applicable new source performance standards, which represent the "best available demonstrated control technology" (BAT) processes, operating methods, or other alternatives, including, where practicable, a standard permitting no discharge of pollutants. Under the Federal Water Pollution Control Act Amendments of 1972, existing sources were to achieve limitations that required the application of the "best practicable control technology currently available" (BPT) by July 1, 1977. By July 1, 1983, existing point sources were to apply BAT. The 1977 amendments modified this phased implementation approach. The July 1, 1977 date for BPT compliance has passed. The Clean Water Act does contain certain limited provisions authorizing EPA to grant extensions of time for compliance with BPT requirements. The requirement for achieving BAT were extended 1 year to July 1, 1984. The Clean Water Act now requires that by July 1, 1984, existing sources of certain identified "conventional pollutants" (including total suspended solids and pH) achieve effluent limitations that require the application of the best conventional pollutant control technology (BCT). Existing sources that discharge any of 65 specifically identified toxic pollutants must apply BAT by July 1, 1984. For other toxic pollutants BAT must be applied within 3 years of promulgation of an applicable effluent limitation. Pollutants that are neither toxic nor conventional have been termed nonconventional pollutants.

EPA has published regulations establishing technology-based effluent limitations applicable to the phosphate industry. BPT and BAT limitations, and new source performance standards were established for the phosphate subcategory of the fertilizer manufacturing point source category.

BPT effluent limitations have been promulgated for phosphate rock mining point sources. BAT limitations and new source performance standards for the phosphate rock mining subcategory were proposed. New source performance standards were promulgated on March 10, 1978. The BAT limitations have not been finally adopted. The BPT limitations and new source performance standards establish limitations on the discharge of total suspended solids (TSS) and pH. It is not clear what action EPA will take to implement the 1977 amendments to the Clean Water Act as they relate to effluent limitations and standards applicable to the phosphate industry. TSS and pH are statutorily defined as conventional pollutants. EPA must determine what discharge limitations will constitute BCT for these parameters.

Under Section 404, a permit from the U.S. Army Corps of Engineers (Corps) is required prior to the discharge of dredged or fill materials into the waters of the United States. Phosphate-mining operations can under certain circumstances lead to the discharge of dredged material. Prior to issuing a Section 404 permit, the Corps is required to consider a number of factors including a "public interest review," and an evaluation of the proposed projects effect on wetlands, fish and wildlife, water quality, and historic, scenic, and recreational values in the area. Although the Corps is the permit-issuing agency, EPA can prohibit or restrict activities for which permits are required if, after notice and opportunity for public hearing, it is determined that the activity will have an unacceptable adverse effect on municipal water supplies, shell fish beds and fishery areas, wildlife, or recreational areas.

Under Section 303, water quality standards existing as of the date of the 1972 amendments are continued in effect. EPA is required to promulgate water quality standards for a State if satisfactory standards are not submitted. The State of Florida Environmental Regulation Commission is currently revising the State of Florida water quality standards.

Section 311 regulates discharges of oil and hazardous substances. The basic thrust concerns spills; the term discharge is defined broadly and may include discharges permitted under the Clean Water Act.

Section 101 of the National Environmental Policy Act (NEPA) established a national policy to "create and maintain conditions under which man and nature can exist in productive harmony and fulfill the needs of future generations of Americans." NEPA established the Council on Environmental Quality (CEQ) and set forth certain "action-forcing" requirements that are found in Section 102 of NEPA.

An EIS on the effects of the phosphate industry in central Florida was completed and issued in 1979.

The Atomic Energy Act is intended to provide a program for Government control of the possession, use, and production of atomic energy and special nuclear material, whether owned by the Government or others. All licensing and related regulatory functions under the Atomic Energy Act, initially held by the Atomic Energy Commission were transferred to the Nuclear Regulatory Commission (NRC) under the Energy Reorganization Act of 1974.

NRC regulations require a specific or general license for a person to receive, possess, use, transfer, deliver, or import any "source material" after removal from its place of deposit in nature. If uranium extracted from phosphoric acid in Florida meets the threshold requirements, then NRC licensing requirements may be applicable.

Congress has enacted several laws in recent years that may potentially require permitting procedures for the phosphate industry. Recent enactments are identified although implementing regulatory programs have not been developed or finalized. These are:

The Safe Drinking Water Act was enacted to protect underground sources of drinking water. An underground injection control program will be required of each State. Guidelines for the programs will be developed by EPA.

The Resource Conservation and Recovery Act (RCRA) provides "cradle to grave" regulatory controls over hazardous waste. Under the RCRA, EPA must adopt regulations for identifying hazardous wastes and their characteristics.

It is not known if any of the wastes generated by the phosphate industry will be classified as hazardous and subject to RCRA regulations.

The Surface Mining Control and Reclamation Act (SMCR) of 1977 deals principally with coal-mining operations. However, Section 709 called for a study of surface mining of minerals other than coal and directed the Council on Environmental Quality to contract with the National Academy of Sciences (NAS) to make such a study. NAS formed the Committee on Surface Mining and Reclamation (COSMAR). The Committee submitted a report in October 1979 that included a study of phosphate operations.

There are other statutes that, directly or indirectly, effect environmental review and permitting. These are listed as follows, but will not be reviewed:

The Rivers and Harbors Act of 1899;

The Fish and Wildlife Coordination Act;

The Ports and Waterways Safety Act of 1972;

The Marine Protection, Research and Sanctuaries Act of 1972;

The Noise Control Act of 1972;

The Coastal Zone Management Act of 1972;

The Marine Mammal Protection Act of 1972;

The Endangered Species Act of 1973;

The Wildland Scenic Rivers Act;

The Soil and Water Resources Conservation Act of 1977;

The Toxic Substances Control Act of 1976;

The Deepwater Port Act of 1974;

and The National Historic Preservation Act of 1966.

A final EIS on phosphate leasing in the Osceola National Forest was published in May 1974. Since that time, the Secretary of the Interior ordered additional studies on the effects of the proposed action on hydrology and endangered species. The U.S. Geological Survey and the U.S. Fish and Wildlife Service submitted reports on these subjects. A supplemental environmental study on the effects of phosphate leasing on 52,000 acres in the Osceola National Forest was ordered. The U.S. Department of the Interior was given the lead responsibility to complete the study. The final supplement was filed in 1979.

The Bureau of Mines through their contractor, ZWI, conducted a 12-month investigation of Florida phosphate resources for entry into the Minerals Availability System (MAS). Data were collected from known literature, mineral interests, now developing or producing phosphate rock, large landowners, and governmental agencies on a regional, deposit summary, or individual prospect whole data base. Operating and capital cost estimates assignable in the MAS to operating or projected (C) deposits were prepared by modeling six case mines; based on nominal ranges of size, age, and quality of ore. These cases provided the basis for development of a computer program to project costs for (R) (other identified deposits). These costs, environmental, geographic, and other relevant data were encoded into the MAS format, as well as probabilistic grade-resource quantification. The report "Evaluation of the Phosphate Deposits of Florida Using the Minerals Availability System" is available from the Bureau of Mines as Open File Report 112-78 from the National Technical Information Service (NTIS), Springfield, Va., PB 286 6481AS.

DOMESTIC PRODUCTION

Marketable phosphate rock production and value are shown in table 1. In 1978, Florida and North Carolina produced 43,258,000 metric tons, 87% of the total marketable phosphate rock; the Western States produced 5,070,000 metric tons, 10%; and Tennessee produced 1,709,000 metric tons, 3%. In 1979, Florida and North Carolina produced 44,256,000 metric tons, 86% of the total marketable phosphate rock; the Western States produced 5,482,000 metric tons, 11%; and Tennessee produced 1,873,000 metric tons, 3%.

Florida and North Carolina.—Production of marketable phosphate rock and value are shown in table 2.

The P_2O_5 content of phosphate ore mined and marketable rock recovered are shown in table 2.

Agrico Chemical Co.; Borden, Inc.; Brewster Phosphates; Gardinier, Inc.; W. R. Grace & Co.; International Minerals & Chemical Corp. (IMC); T. A. Minerals Corp.; Mobil Chemical Co.; Estech General Chemical Co.; and USS Agri-Chemicals produced marketable phosphate rock from the Bone Valley Formation in central Florida and Occidental Chemical Co. produced from a similar-type matrix in northern Florida. Howard Phosphate Co., Kellogg Co., Loncala Phosphate Co., and Manko Co., Inc., mined about 34,000 and 25,000 metric tons of soft rock in 1978 and 1979, respectively, from tailing ponds associated with past hard rock phosphate mines in central Florida.

In North Carolina, Texasgulf, Inc., was the only company producing phosphate rock. The addition of dredges and draglines increased mining capacity to 4.5 million metric tons per year. North Carolina Phosphate Corp., owned by Agrico Chemical Co. and Kennecott Copper Corp., completed the permitting process and started dredging

South Creek for eventual barge traffic to Moorehead City. Mining plans and schedules have not been announced.

Occidental Chemical Co., a division of Occidental Petroleum Corp., produced phosphate rock from the Suwannee River mine in north Florida. The Swift Creek mine was reactivated during 1979. The superphosphoric acid (SPA) plant at the Suwannee River mine was expanded and a new SPA complex at the Swift Creek mine was constructed. After completion in 1979, it will supply 50% of the SPA that is planned to be shipped to the U.S.S.R. Occidental plans to barter 1.0 million metric tons per year of SPA and receive 1.4 million metric tons of ammonia, 1.0 million metric tons of urea, and 1.0 million metric tons of potash.

In central Florida, the areawide moratorium on new mines was lifted when the central Florida EIS was completed and issued. Agrico Chemical Co. operated the Payne Creek and Fort Green mines. The Saddle Creek mine that was shut down was reopened and if economics are favorable, is expected to produce through 1983. Asamera Minerals, Inc., closed their debris-recovery operation near Lakeland, Fla. Although Borden, Inc., started the Big Four mine in Hillsborough County, they continued to operate part of the closed Tenoroc mine for part of the year before closing the mine completely in 1978. Brewster Phosphates continued to operate both the older Haynesworth mine and the new Fort Lonesome mine in 1978-79. CF Industries opened the first phosphate rock mine in Hardee County in September 1978.

Gardinier started a new uranium oxide recovery plant south of Tampa, Fla., in 1979. W. R. Grace produced phosphate rock from the Bonny Lake and Hookers Prairie mines. The permitting for a new mine, Four Corners, in southeast Hillsborough County, is complete and will be a joint venture of Grace and IMC. IMC will increase the capacity of their phosphoric acid plant near Mulberry, Fla. When completed the capacity will be about 1.4 million metric tons of phosphoric acid.

IMC started constructing a uranium recovery plant near Mulberry, Fla., at the New Wales chemical complex. It will be designed to recover 340,200 kilograms of uranium oxide per year from 762,000 metric tons per year of phosphoric acid. It was expected to start operating in late 1979.

Recovery of uranium from wet process phosphoric acid is proving to be economically attractive to operators and also produces a purer phosphoric acid. The status of solvent-extraction facilities to recover uranium oxide is as follows: Uranium Recovery Corp. is operating a 129,270-kilogram-per-year U_3O_8 plant near Mulberry, Fla. Freeport Uranium is operating a 313,000-kilogram-per-year U_3O_8 recovery plant at Uncle Sam, La., and is planning to startup a 159,000-kilogram-per-year U_3O_8 plant at Donaldsonville, La., in mid-1980. Wyoming Mineral Corp. started a 193,000-kilogram-per-year U_3O_8 recovery plant at Pierce, Fla. IMC, in addition to their Mulberry plant production, plans to purchase 0.57 million kilograms of U_3O_8 from CF Industries phosphoric acid plants at Bartow and Plant City, Fla. The phosphoric acid will be processed at the New Wales plant into yellowcake. In Florida, about 3.5 metric tons of phosphate rock is required to produce 1 metric ton of phosphoric acid. A metric ton of phosphoric acid will yield about 0.45 kilogram of yellowcake. After filtering through activated carbon and oxidation the phosphoric acid is treated with an organic solvent which extracts the uranium oxide. The phosphoric acid is returned to the phosphate plant for normal processing.

Western States.—Production of marketable phosphate rock and value are shown in table 2. Production of phosphate rock for agricultural purposes in the Western States was 2,018,000 and 2,006,000 metric tons, in 1978 and 1979, respectively. Phosphate rock used in electric furnaces was 2,592,000 and 2,328,000 metric tons in 1978 and 1979, respectively.

The average grade of mined phosphate ore was 25% P_2O_5 in 1978-79. The average grade of mined phosphate ore used without beneficiation was 26.3% and 26.5% P_2O_5 in 1978 and 1979, respectively. The average grade of beneficiated phosphate rock was 32.0% and 31.7% P_2O_5 in 1978 and 1979, respectively. The average grade of all used as mined and beneficiated phosphate rock was 29.0% and 29.1% P_2O_5 in 1978 and 1979, respectively. Of the total phosphate rock produced in the Western States, 53.3% was used without beneficiation and 46.7% was beneficiated in 1978. In 1979, 50.2% was unbeneficiated and 49.8% was beneficiated. The weight recovery of the beneficiated concentrates was 59.7% and the P_2O_5 recovery was 78.1% in 1978. In 1979, the weight recovery of concentrates was 50.9% and the P_2O_5 recovery was 66.6%.

Conda Partnership, Monsanto Industrial Chemicals Co., J. R. Simplot Co., and Stauffer Chemical Co. mined and processed phosphate rock in Idaho. In Montana, Cominco American, Inc., operated an underground phosphate rock mine near Garrison. Stauffer Chemical Co. operated the Vernal, Utah, mine. Mining at Leefe, Wyo., was discontinued by Stauffer Chemical Co. in 1978.

Beker Industries Corp. and Western Co-Operative Fertilizers Ltd., a Canadian corporation, negotiated to form the "Conda Partnership." No new mines were developed in the Western States during 1978-79.

Tennessee.—Production of marketable phosphate rock and value are shown in table 2. The average grade of ore mined was 21.2% P_2O_5 in 1978 and 20.9% in 1979. The average weight recovery was 56% in 1978 and 58.3% in 1979. The P_2O_5 recovery was 68.4% in 1978 and 69.7% in 1979. The average grade of marketable phosphate rock was 25.9% in 1978 and 24.9% in 1979.

Hooker Chemical Co., Monsanto Industrial Chemicals Co., and Stauffer Chemical Co. mined and beneficiated phosphate rock in Tennessee for reduction to elemental phosphorus in electric furnaces.

Table 2.—Production of phosphate rock in the United States, by State

(Thousand metric tons and thousand dollars)

	Mine production		Mine production used directly		Beneficiated production		Marketable production		
	Rock	P_2O_5 content	Rock	P_2O_5 content	Rock	P_2O_5 content	Rock	P_2O_5 content	Value
1978:									
Florida and North Carolina	163,712	18,951	34	7	43,224	13,414	43,258	13,421	817,165
Tennessee	3,052	646	--	--	1,709	442	1,709	442	14,047
Western States[1]	6,664	1,681	2,704	711	2,366	758	5,070	1,469	97,607
Total[2]	173,429	21,278	2,738	718	47,298	14,614	50,037	15,332	928,820
1979:									
Florida and North Carolina	174,430	20,360	25	5	44,231	13,776	44,256	13,781	918,555
Tennessee	3,211	670	--	--	1,873	467	1,873	467	14,770
Western States[1]	8,117	2,027	2,750	728	2,732	867	5,482	1,595	112,329
Total[2]	185,757	23,056	2,775	733	48,835	15,110	51,611	15,843	1,045,655

[1] Includes Alabama, Idaho, Montana, Utah, and Wyoming.
[2] Data may not add to totals shown because of independent rounding.

CONSUMPTION AND USES

Apparent consumption of marketable phosphate rock, defined as the quantity sold or used plus imports minus exports, is shown in table 1. Table 1 also reports the quantity of phosphate rock sold or used.

The consumption pattern as reported by producers is shown in table 3.

The percent distribution by grade of marketable phosphate rock consumed in the United States and sold in the export market in 1978-79 is compared with the distribution patterns for prior years 1975-77 in the following tabulation. Trends in U.S. grade distribution pattern of phosphate rock are not discernible from these data because of the mix of furnace and wet process phosphoric acid-phosphate rock feed in the total distribution pattern.

Grade, percent BPL[1] content	Distribution (percent)				
	1975	1976	1977	1978	1979
Less than 60	9.4	7.8	5.7	6.2	5.4
60 to 66	14.7	14.6	11.6	13.3	14.2
66 to 70	48.4	53.8	57.3	54.3	56.3
70 to 72	10.8	9.4	12.2	13.3	13.6
72 to 74	10.7	8.3	7.4	8.6	6.6
Over 74	6.0	6.1	5.8	4.3	3.9

[1] 1.0% BPL (bone phosphate of lime or tricalcium phosphate) = 0.458% P_2O_5.

Florida and North Carolina.—The quantity of phosphate rock sold or used is shown in table 4. Table 5 shows the distribution of phosphate rock sold or used in Florida and

North Carolina by domestic and export tonnages.

The percent distribution by grade of the marketable rock sold or used from Florida and North Carolina, including exports, is tabulated for the years 1975-79.

Grade, percent BPL[1] content	Distribution (percent)				
	1975	1976	1977	1978	1979
Less than 60	0.1	0.2	0.1	0.1	0.2
60 to 66	14.8	13.4	10.5	11.9	12.6
66 to 70	55.0	60.2	62.7	60.8	62.4
70 to 72	11.2	11.2	14.1	15.7	12.7
72 to 74	11.5	7.7	5.9	6.5	7.6
Over 74	7.4	7.3	6.7	5.0	4.6

[1] 1.0% BPL (bone phosphate of lime or tricalcium phosphate) = 0.458% P_2O_5.

Western States.—The quantity of marketable phosphate rock sold or used is shown in tables 4-5. Of the total sold or used in 1978, 81.3% was consumed in the United States and 18.7% was exported to Canada. In 1979, 79.7% was consumed in the United States and 20.3% was exported to Canada. The percent distribution by grade of marketable rock sold or used from the Western States for 1975-79 is shown in the following tabulation:

Grade, percent BPL[1] content	Distribution (percent)				
	1975	1976	1977	1978	1979
Less than 60	38.8	37.8	29.7	32.6	27.4
60 to 66	13.2	18.5	16.3	17.9	18.9
66 to 70	25.9	28.5	31.5	23.2	26.8
70 to 72	12.2	--	--	--	26.5
72 to 74	9.9	15.2	22.6	26.3	.4

[1] 1.0% BPL (bone phosphate of lime or tricalcium phosphate) = 0.458% P_2O_5.

Tennessee.—The quantity and value of marketable phosphate rock sold or used is shown in table 4. All of this rock was used in electric furnaces to produce elemental phosphorus and industrial chemicals. Most of the phosphorus was converted into intermediate phosphoric acid, the base for a large number of sodium, calcium, and potassium chemicals.

The percent distribution by grade of marketable rock sold or used in Tennessee for 1975-79 is shown in the following tabulation:

Grade, percent BPL[1] content	Distribution (percent)				
	1975	1976	1977	1978	1979
Less than 60	80.9	72.1	75.4	68.3	60.3
60 to 66	17.5	26.8	24.6	31.7	37.0
66 to 70	1.6	1.1	--	--	2.7

[1] 1.0% BPL (bone phosphate of lime or tricalcium phosphate) = 0.458% P_2O_5.

Table 5 shows the phosphate rock sold or used by producers by use, domestic (agriculture or industrial) and exports, and by State groupings.

The recent history of phosphate rock sold or used by producers by kind is shown in tables 6-8 for Florida, Tennessee, and the Western States.

Table 3.—Phosphate rock sold or used by producers in the United States, by use

(Thousand metric tons)

Use	1978		1979	
	Rock	P_2O_5 content	Rock	P_2O_5 content
Domestic:				
Wet process phosphoric acid	29,022	8,907	31,674	9,754
Normal superphosphate	298	98	294	95
Triple superphosphate	1,781	571	1,662	533
Defluorinated rock	198	65	243	82
Direct applications	39	7	36	7
Elemental phosphorus	4,371	1,135	4,580	1,188
Ferrophosphorus	200	52	217	56
Total[1]	35,904	10,830	38,706	11,714
Exports[2]	12,870	4,118	14,358	4,611
Grand total[1]	48,774	14,948	53,063	16,325

[1] Data may not add to totals shown because of independent rounding.
[2] Exports reported to the Bureau of Mines by companies.

Table 4.—Phosphate rock sold or used by producers in the United States, by grade and State in 1979

(Thousand metric tons and thousand dollars)

Grade, percent BPL[1] content	Florida and North Carolina			Tennessee		
	Rock	P_2O_5 content	Value	Rock	P_2O_5 content	Value
Below 60	72	16	1,103	1,291	303	9,185
60 to 66	5,713	1,632	129,539	792	224	7,325
66 to 70	28,384	8,790	531,701	57	17	498
70 to 72	W	W	W	--	--	--
72 to 74	W	W	W	--	--	--
Plus 74	2,075	721	55,767	--	--	--
Total[2]	45,484	14,194	935,672	2,140	545	17,008

Grade, percent BPL[1] content	Western States			Total United States		
	Rock	P_2O_5 content	Value	Rock	P_2O_5 content	Value
Below 60	1,487	371	22,778	2,850	691	33,066
60 to 66	1,030	286	15,051	7,534	2,143	151,915
66 to 70	1,458	453	34,137	29,899	9,260	566,337
70 to 72	W	W	W	7,228	2,341	167,645
72 to 74	W	W	W	3,476	1,169	88,788
Plus 74	--	--	--	2,075	721	55,767
Total[2]	5,439	1,585	110,837	53,063	16,325	1,063,517

W Withheld to avoid disclosing company proprietary data.

[1] 1.0% BPL (bone phosphate of lime or tricalcium phosphate) = 0.458% P_2O_5.

[2] Data may not add to totals shown because of independent rounding.

Table 5.—Phosphate rock sold or used by producers, by use and State

(Thousand metric tons)

Use	Florida and North Carolina		Tennessee		Western States		Total United States	
	Rock	P_2O_5 content	Rock	P_2O_5 content	Rock	P_2O_5 content	Rock	P_2O_5 content
1978:								
Domestic:								
Agricultural	29,314	8,998	--	--	2,018	646	31,332	9,644
Industrial	291	84	1,688	434	2,592	668	4,571	1,186
Total[1]	29,605	9,082	1,688	434	4,611	1,314	35,904	10,830
Exports[2]	11,810	3,785	--	--	1,060	333	12,870	4,118
Total[1]	41,415	12,866	1,688	434	5,671	1,647	48,774	14,948
1979:								
Domestic:								
Agricultural	31,902	9,835	--	--	2,006	635	33,909	10,470
Industrial	329	96	2,140	545	2,328	603	4,797	1,244
Total[1]	32,231	9,930	2,140	545	4,334	1,238	38,706	11,714
Exports[2]	13,253	4,264	--	--	1,105	347	14,358	4,611
Total[1]	45,484	14,194	2,140	545	5,439	1,585	53,063	16,325

[1] Data may not add to totals shown because of independent rounding.

[2] Exports reported to the Bureau of Mines by companies.

Table 6.—Florida phosphate rock sold or used by producers, by kind

(Thousand metric tons and thousand dollars)

Year	Land pebble[1]				Soft rock				Total[2]			
			Value				Value				Value	
	Rock	P_2O_5 content	Total	Average per ton	Rock	P_2O_5 content	Total	Average per ton	Rock	P_2O_5 content	Total	Average per ton
1975	34,369	10,782	926,813	26.97	25	5	503	20.12	34,394	10,787	927,316	26.96
1976	33,886	10,568	774,517	22.86	29	6	580	20.00	33,915	10,574	775,096	22.85
1977	40,970	12,838	726,950	17.74	25	5	504	20.16	40,994	12,843	727,454	17.75
1978	41,388	12,861	778,339	18.81	27	6	537	19.89	41,415	[r]12,866	778,876	18.81
1979	45,459	14,189	935,127	20.57	26	5	545	20.96	45,484	14,194	935,672	20.57

[r] Revised.

[1] Includes North Carolina.

[2] Data may not add to totals shown because of independent rounding.

Table 7.—Tennessee phosphate rock sold or used by producers

(Thousand metric tons and thousand dollars)

Year	Rock	P_2O_5 content	Value	
			Total	Average per ton
1975	2,171	560	29,921	13.78
1976	1,731	448	15,326	8.85
1977	1,723	436	14,064	8.16
1978	1,688	434	13,833	8.19
1979	2,140	545	17,008	7.95

Table 8.—Western States phosphate rock sold or used by producers

(Thousand metric tons and thousand dollars)

Year	Rock	P_2O_5 content	Value	
			Total	Average per ton
1975	5,565	1,596	95,759	17.24
1976	4,877	1,383	66,767	13.69
1977	4,719	1,382	87,566	18.56
1978	5,671	1,647	108,669	19.16
1979	5,439	1,585	110,837	20.38

STOCKS

Stocks of marketable phosphate rock increased from 13.8 million metric tons at the beginning of 1978 to a record level of 15.7 million metric tons at the end of 1978. The principal gain in stock levels was in Florida and North Carolina, where the increase was from 11.9 million metric tons at the beginning of the year and the level was 14.1 million metric tons at the end of 1978. Most of this gain occured in Florida. In Tennessee and the Western States, stocks were not a factor, but were maintained to assure a continuous supply to either electric furnaces or wet process acid plants and to mitigate the difficulty of moving frozen ore in the winter months of the year. In 1979, inventories gradually declined throughout the year and by the end of the year stood at 14.4 million metric tons.

PRICES

Prices of phosphate rock sold in either the domestic or international market are negotiated between buyers and sellers. The content of the contracts are not public information and prices are not published. Even if price lists are published, prices do not reflect the effect of long-term contracts or adjustments individually negotiated. Both the Phosphate Rock Export Association, Tampa, Fla., and the Moroccan Office Cherifien des Phosphates, Paris, France, have in the past published price lists. Although the practice of publishing prices has been intermittent, price levels that were average and realized are available for the record. Phosphate Rock Export Association prices are shown in table 9.

The rail freight costs in central Florida for phosphate rock increased from $1.98 per metric ton in 1977 to $2.20 per metric ton in 1978 and to an average of $2.33 per metric ton in 1979. Terminal charges increased to $0.28 per metric ton in 1978 and to an average $1.45 per metric ton in 1979.

The Moroccan Office Cherifien des Phosphates made the following changes, as shown in table 10, in the pricing structure of phosphate rock.

The prices shown in the preceeding tables can only give an indication of prevailing market prices and certainly not the price for any one specific contract. Discounts, freight costs, and profit margins will also have an effect on landed prices.

Producing companies report the value[4] of each grade of marketable phosphate rock sold or used semiannually to the Bureau of Mines. The average 1978 and 1979 unit values of marketable phosphate rock reported by producers, was $18.48 and $20.04 per metric ton f.o.b. plant, respectively. These were both higher than the $17.48 per metric ton value reported in 1977. The average unit value of land-pebble phosphate rock reported sold or used in the domestic and export markets from Florida and North Carolina increased from $17.75 per metric ton in 1977 to $18.81 and $20.57 per metric ton in 1978 and 1979, respectively. In the Western States, the unit value of marketable phosphate rock sold or used increased from $18.56 per metric ton in 1977 to $19.16 and $20.38 per metric ton in 1978 and 1979, respectively. The unit value of marketable rock used in Tennessee was $8.19 per metric ton in 1978, and $7.95 per metric ton in 1979. It was $8.16 per metric ton in 1977.

The average unit value of phosphate rock exported from the United States increased from $21.81 per metric ton in 1977 to $23.10 and $24.83 per metric ton, f.o.b. mine in 1978 and 1979, respectively. The unit value of phosphate rock exported from Florida and North Carolina increased from $21.64 per metric ton in 1977, to $22.73 and $24.60 per metric ton, f.o.b. mine in 1978 and 1979, respectively. The unit value of phosphate rock exported from the Western States increased from $26.45 per metric ton in 1977 to $27.28 and $27.52 per metric ton, f.o.b. mine in 1978 and 1979, respectively. Tennessee rock was not exported.

Tables 11-13 show the price or value of phosphate rock domestically sold or consumed and exported, by grade, for Florida and North Carolina, the Western States, and Tennessee, in dollars per metric ton f.o.b. mine.

Table 14 shows the price or value of phosphate rock domestically sold or used and exported by grade from the United States in dollars per metric ton f.o.b. mine.

Table 9.—Phosphate rock export association average realized prices, per metric ton, unground, f.o.b. vessel Tampa Range or Jacksonville, Fla.

Grade, percent BPL[1] content	December 1978[2]	1979[3]
77	--	$38.00
75	$34.55	34.00
72	32.55	30.00
70	30.55	26.00
68	28.55	25.00
66	26.55	25.00

[1] 1.0% BPL (bone phosphate of lime or tricalcium phosphate) = 0.458% of P_2O_5.
[2] Estimated selling price including $0.55 severance tax.
[3] Estimated selling price including $1.15 severance tax.

Table 10.—Moroccan phosphate rock export prices, per metric ton, f.a.s. Safi or Casablanca

Grade, percent BPL[1] content	1978	1979
Khouribga:		
76 to 77	$41.00	$43.00
75 to 76	37.00	42.00
72 to 73	32.00	40.00
70 to 71	--	43.00
Youssoufia:		
68 to 69	30.00	35.25
74 to 75	--	42.00

[1] 1.0% BPL (bone phosphate of lime or tricalcium phosphate) = 0.458% P_2O_5.

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Table 11.—Price or value of Florida and North Carolina phosphate rock

(Dollars per metric ton, f.o.b. mine)

Grade, percent BPL[1] content	1978			1979		
	Domestic	Export	Average	Domestic	Export	Average
Less than 60	13.23	--	13.23	12.12	--	12.12
60 to 66	19.25	18.23	19.15	22.90	21.06	22.68
66 to 70	16.03	21.54	17.07	17.65	23.48	18.73
70 to 72	19.73	20.79	20.28	20.37	23.62	22.35
72 to 74	19.81	26.41	25.10	22.76	26.40	25.54
Over 74	23.44	29.22	26.24	22.09	30.85	26.87
Average	17.24	22.73	18.81	18.91	24.60	20.57

[1] 1.0% BPL (bone phosphate of lime or tricalcium phosphate)= 0.458% P_2O_5.

Table 12.—Price or value of Western States phosphate rock

(Dollars per metric ton, f.o.b. mine)

Grade, percent BPL[1] content	1978			1979		
	Domestic	Export	Average	Domestic	Export	Average
Less than 60	14.82	--	14.82	15.31	--	15.31
60 to 66	8.77	28.18	13.87	11.46	29.31	14.62
66 to 70	18.57	27.89	20.59	21.73	28.66	23.41
72 to 74	27.13	26.46	26.90	24.84	24.83	24.84
Average	17.30	27.28	19.16	18.56	27.52	20.38

[1] 1.0% BPL (bone phosphate of lime or tricalcium phosphate)= 0.458% P_2O_5.

Table 13.—Price or value of Tennessee phosphate rock

(Dollars per metric ton, f.o.b. mine)

Grade, percent BPL[1] content	1978	1979
Less than 60	7.75	7.11
60 to 66	9.15	9.25
66 to 70	--	8.72
Average	8.19	7.95

[1] 1.0% BPL (bone phosphate of lime or tricalcium phosphate)= 0.458% P_2O_5.

Table 14.—Price or value of United States phosphate rock

(Dollars per metric ton, f.o.b. mine)

Grade, percent BPL[1] content	1978			1979		
	Domestic	Export	Average	Domestic	Export	Average
Less than 60	12.10	--	12.10	11.51	--	11.51
60 to 66	16.92	21.66	17.49	19.82	22.79	20.16
66 to 70	16.15	21.90	17.24	17.82	23.80	18.94
70 to 72	19.73	20.79	20.28	22.17	23.98	23.19
72 to 74	24.56	26.42	25.74	22.79	26.89	25.54
Over 74	23.44	29.22	26.24	22.09	30.85	26.87
Average	16.82	23.10	18.48	18.27	24.83	20.04

[1] 1.0% BPL (bone phosphate of lime or tricalcium phosphate)= 0.458% P_2O_5.

FOREIGN TRADE

In 1978 and 1979, producers reported that exports of phosphate rock from the United States were 12,870,000 and 14,358,000 metric tons, respectively.

Imports of phosphate rock increased significantly from 158,000 metric tons in 1977 to 908,000 and 886,000 metric tons in 1978 and 1979, respectively, as reported by the Bureau of the Census. Morocco supplied 94% and 97% of the total imports in 1978 and 1979, respectively. The first full year of imports from Morocco was 1978.

Tables 15-21 are included to show the quantities of phosphate rock, phosphate fertilizers, and phosphate intermediates exported from the United States for 1978-79.

Table 22 lists the imports of phosphate fertilizers and chemicals during 1978-79.

Table 15.—U.S. exports of phosphate rock,[1] by country

(Thousand metric tons and thousand dollars)

Destination	1978		1979	
	Quantity	Value[2]	Quantity	Value[2]
Argentina	1	135	(3)	80
Australia	--	--	323	8,289
Austria	33	1,094	65	2,146
Belgium-Luxembourg	729	20,459	874	25,394
Brazil	347	10,858	289	12,289
Canada	3,270	69,216	3,396	89,837
China: Taiwan	32	1,178	99	3,228
Colombia	69	2,362	48	1,787
Costa Rica	3	71	6	145
Denmark	98	3,280	86	2,737
Ecuador	15	494	11	372
El Salvador	15	409	8	204
Finland	35	931	101	3,482
France	999	26,518	983	27,771
Germany, Federal Republic of	817	20,754	1,008	26,402
India	200	7,035	251	8,668
Indonesia	--	--	41	1,496
Iran	478	12,451	--	--
Ireland	22	618	31	856
Italy	247	7,108	340	9,259
Japan	1,477	46,596	1,769	55,725
Korea, Republic of	1,515	45,688	1,727	56,505
Mexico	394	10,345	372	8,772
Netherlands	771	20,050	630	17,180
New Zealand	(3)	4	82	2,557
Norway	120	3,286	78	2,322
Peru	10	331	4	141
Philippines	50	1,824	116	4,439
Poland	893	25,442	742	21,382
Portugal	4	113	--	--
Romania	398	11,023	646	21,824
Spain	41	743	30	541
Sweden	115	3,464	97	3,199
United Kingdom	478	12,175	411	10,666
Uruguay	11	357	29	1,189
Other	5	252	2	289
Total[4]	13,698	366,795	14,787	431,991

[1] For 1978 and 1979, Florida phosphate rock and other phosphate rock are reported in a single class.
[2] All values f.a.s. (free alongside ship).
[3] Less than 1/2 unit.
[4] Data may not add to totals shown because of independent rounding.

Source: U.S. Bureau of the Census.

Table 16.—U.S. exports of superphosphates more than 40% P_2O_5, by country

(Thousand metric tons and thousand dollars)

Destination	1978		1979	
	Quantity	Value[1]	Quantity	Value[1]
Argentina	12	1,150	46	5,864
Australia	7	676	--	--
Bangladesh	31	2,949	--	--
Belgium-Luxembourg	128	12,108	113	13,890
Brazil	256	24,299	332	46,013
Canada	46	4,526	108	13,946
Chile	75	6,997	125	16,448
China, mainland	31	3,796	86	13,706
Colombia	21	2,482	19	2,494
Costa Rica	9	958	9	1,192
Czechoslovakia	20	1,783	96	9,596
Dominican Republic	6	733	4	896
France	90	8,865	85	9,594
Germany, Federal Republic of	191	17,720	--	--
Guyana	5	663	2	432
Hungary	58	5,801	117	12,256
Indonesia	166	16,533	44	6,089
Ireland	68	6,632	63	7,724
Italy	17	1,664	20	2,150
Jamaica	1	206	1	112
Japan	75	7,899	39	5,533
Malaysia	2	201	1	189
Netherlands	7	679	5	500
Niger	(2)	89	1	111
Panama	(2)	34	--	--
Peru	11	990	12	1,977
Singapore	27	2,711	73	10,027
South Africa, Republic of	2	245	--	--
Turkey	25	2,369	--	--
United Kingdom	(2)	1	--	--
Uruguay	5	554	23	2,997
Venezuela	--	--	7	1,300
Yugoslavia	38	3,872	--	--
Other	33	3,070	12	1,699
Total[3]	1,462	143,223	1,443	185,973

[1] All values f.a.s. (free alongside ship).
[2] Less than 1/2 unit.
[3] Data may not add to totals shown because of independent rounding.

Source: U.S. Bureau of the Census.

Table 17.—U.S. exports of superphosphates, less than 40% P_2O_5, by country

Destination	1978		1979	
	Quantity (metric tons)	Value[1] (thousands)	Quantity (metric tons)	Value[1] (thousands)
Argentina	--	--	3,920	$800
Bahamas	18	$3	13	1
Belgium	11,776	1,110	--	--
Bermuda	--	--	19	3
Brazil	8,904	276	7,496	726
Canada	1,794	46	1,199	50
Dominican Republic	930	97	--	--
France	8,722	946	--	--
Mexico	--	--	137	3
Peru	--	--	2,395	229
Thailand	--	--	11,163	1,322
Total[2]	32,144	2,480	26,151	2,935

[1] All values f.a.s. (free alongside ship).
[2] Data may not add to totals shown because of independent rounding.

Source: U.S. Bureau of the Census.

Table 18.—U.S. exports of diammonium phosphates, by country

(Thousand metric tons and thousand dollars)

Destination	1978		1979	
	Quantity	Value[1]	Quantity	Value[1]
Argentina	42	5,728	74	11,856
Australia	60	8,351	30	4,468
Bangladesh	63	11,229	31	6,492
Belgium-Luxembourg	364	46,730	324	51,920
Bolivia	2	444	2	278
Brazil	393	51,913	487	83,804
Canada	216	21,500	163	25,494
Chile	--	--	34	6,668
China:				
Mainland	125	19,749	23	3,723
Taiwan	5	175	--	--
Colombia	35	4,659	38	6,587
Costa Rica	28	3,850	23	3,710
Cyprus	7	1,016	--	--
Dominican Republic	25	3,368	37	6,426
Ecuador	9	1,306	12	1,905
El Salvador	45	5,961	38	5,688
Ethiopia	--	--	115	27,219
France	177	23,092	191	29,414
French West Indies	1	199	2	400
Germany, Federal Republic of	64	8,364	21	3,519
Guatemala	1	169	27	3,758
Honduras	2	223	2	321
India	505	66,434	558	96,650
Iran	38	6,079	--	--
Ireland	47	6,387	38	5,859
Italy	720	96,901	866	150,822
Ivory Coast	13	1,838	10	1,536
Japan	130	17,558	141	22,553
Libya	--	--	27	4,359
Malaysia	5	708	5	737
Mauritania	7	1,047	--	--
Mexico	178	22,667	140	16,486
Mozambique	19	2,466	--	--
Netherlands	--	--	37	5,378
New Zealand	14	1,801	27	4,042
Nicaragua	16	2,203	10	1,478
Pakistan	144	20,528	85	13,691
Panama	2	427	--	--
Peru	22	2,903	15	2,490
Singapore	--	--	4	612
South Africa, Republic of	15	2,151	--	--
Spain	--	--	62	9,667
Thailand	71	9,097	55	9,389
Turkey	213	31,706	170	29,520
United Kingdom	--	--	(2)	12
Uruguay	35	4,746	50	8,809
Venezuela	10	1,689	11	1,953
Yugoslavia	58	7,976	36	5,923
Other	3	263	3	571
Total[3]	3,929	525,610	4,026	676,194

[1] All values f.a.s. (free alongside ship).

[2] Less than 1/2 unit.

[3] Data may not add to totals shown because of independent rounding.

Source: U.S. Bureau of the Census.

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Table 19.—U.S. exports of phosphoric acid, less than 65% P_2O_5, by country [1]

(Thousand metric tons P_2O_5 and thousand dollars)

Destination	1979	
	Quantity	Value[2]
Brazil	327	65,448
Canada	5	1,298
Colombia	26	4,069
Czechoslovakia	6	949
El Salvador	14	2,250
Germany, Federal Republic of	6	1,773
India	193	33,521
Indonesia	34	7,552
Netherlands	18	4,519
Turkey	39	8,941
U.S.S.R	8	951
Other	(3)	52
Total[4]	677	131,324

[1] Data are not available for 1978.
[2] All values f.a.s. (free alongside ship).
[3] Less than 1/2 unit.
[4] Data may not add to totals shown because of independent rounding.

Source: U.S. Bureau of the Census.

Table 20.—U.S. exports of phosphoric acid, more than 65% P_2O_5, by country [1]

(Thousand metric tons P_2O_5 and thousand dollars)

Destination	1979	
	Quantity	Value[2]
Brazil	2	370
Canada	6	1,553
Colombia	5	662
U.S.S.R	493	92,699
Other	(3)	4
Total[4]	505	95,289

[1] Data are not available for 1978.
[2] All values f.a.s. (free alongside ship).
[3] Less than 1/2 unit.
[4] Data may not add to totals shown because of independent rounding.

Source: U.S. Bureau of the Census.

Table 21.—U.S. exports of elemental phosphorus, by country

Destination	1978		1979	
	Quantity (metric tons)	Value[1] (thousands)	Quantity (metric tons)	Value[1] (thousands)
Argentina	10	$19	1,113	$1,400
Australia	150	161	138	154
Belgium-Luxembourg	55	62	37	53
Brazil	6,815	7,461	8,348	10,118
Canada	1,314	1,138	1,204	1,354
Chile	11	9	5	10
China: Taiwan	17	23	36	43
Colombia	10	12	--	--
Dominican Republic	(2)	1	--	--
France	--	--	4	24
Germany, Federal Republic of	18	20	--	--
Haiti	4	1	--	--
India	--	--	83	110
Indonesia	2	1	--	--
Italy	--	--	3	33
Japan	3,614	4,565	4,606	5,322
Mexico	8,341	10,243	13,934	16,931
Netherlands	35	18	--	--
Philippines	2	1	5	6
Saudi Arabia	--	--	1	5
South Africa, Republic of	67	45	--	--
Switzerland	17	18	60	77
Trinidad and Tobago	(2)	1	--	--
United Kingdom	96	121	19	23
Uruguay	1	1	--	--
Other	--	--	8	12
Total[3]	20,580	23,920	29,604	35,675

[1] All values f.a.s. (free alongside ship).
[2] Less than 1/2 unit.
[3] Data may not add to totals shown because of independent rounding.

Source: U.S. Bureau of the Census.

Table 22.—U.S. imports for consumption of phosphate rock and phosphatic materials

(Thousand metric tons and thousand dollars)

Fertilizer	1978		1979	
	Quantity	Value[2]	Quantity	Value[2]
Phosphates, crude and apatite[1]	908	24,378	886	21,595
Phosphatic fertilizers and fertilizer materials	7	1,031	21	3,014
Ammonium phosphates, used as fertilizers	295	36,409	313	42,356
Bone ash, bone dust, bone meal, and bones ground, crude or steamed	6	1,357	5	1,152
Dicalcium phosphate	(3)	61	1	275
Basic slag	17	170	15	169
Manures including guano	(3)	2	(3)	10
Phosphorus	(3)	968	(3)	1,264
Phosphoric acid	1	221	(3)	125
Phosphoric acid, fertilizer grade	50	6,652	83	9,090
Normal superphosphate	15	1,392	15	1,992
Triple superphosphate	22	2,369	23	3,582

[1] Limited to only imports from phosphate rock producing countries in 1978 and 1979; Mexico, Morocco, Netherlands Antilles in 1978, and Morocco and Netherlands Antilles in 1979.

[2] Declared customs valuation.

[3] Less than 1/2 unit.

Source: U.S. Bureau of the Census.

WORLD REVIEW

World phosphate rock production increased in 1978 to 125, and in 1979 to an estimated 128 million metric tons. The upward trend continued from levels of 107 and 116 million metric tons in 1976 and 1977, respectively. Both Morocco and U.S. production increases were the principal reasons for the improvement in 1978-79. Phosphate rock was in good supply during these years and is forecast to be in good supply in 1980 as well. The only problems that may develop may be in logistic constraints. World phosphate reserves appear to be adequate well into the next century and as prices rise to reflect higher production costs, the reserve levels should increase. Foreign government involvement in phosphate rock production has caused some mine developments to occur without regard for a specific mine's economic viability. This trend is expected to continue.

The production pattern in the world has not changed. The United States, Morocco, and the U.S.S.R. are still the principal world producing countries. Expansion plans and activity are noted in Israel, Jordan, Tunisia, and Morocco. Brazil is working to become self-sufficient in phosphate and Queensland Phosphates Ltd., suspended mining phosphate rock in 1978 in Australia.

The major consuming countries were the United States and the U.S.S.R. They used about one-half of the worlds supply of phosphate rock. Japan, mainland China, France, Poland, and Australia were major consuming countries.

The United States, Morocco, and the U.S.S.R. were the principal exporting countries. Exports from the U.S.S.R. were down by 5.9% in 1978 and now represent only 16% of the U.S.S.R.'s production. The U.S.S.R. will likely become a net importer of phosphate within a few years. Morocco accounts for about one-third of the world's phosphate exports from about 15% of of the world's production. Exports from the United States, after a surge in 1977, appear to have stabilized. Tunisia, Togo, Senegal, and Jordan are increasing the level of exports of phosphate rock.

Algeria.—Production of phosphate rock was 707,000, 742,000 and 1,173,000 metric tons in 1975, 1976, and 1977, respectively. Production was 1,136,000 metric tons in 1978. Based on the first three quarters of the year data, production in 1979 is projected to be 1,100,000 metric tons. About 52% of Algeria's production is less than 65% BPL and 48% ranges from 73% to 77% BPL. Exports of phosphate rock from Algeria increased from 290,000 metric tons in 1975 to 1,136,000 metric tons in 1978. About 42% of the rock exported was in the grade range of 73% to 77% BPL. Exports were made in 1978 to Austria, Finland, France, Greece, Italy, Czechoslovakia, Hungary, Poland, Brazil, and the Republic of Korea.

Australia.—The decision was made by Broken Hill South to close the phosphate rock mining subsidiary, Queensland Phosphate Ltd., after large losses were incurred in 1977. The Duchess mine rock was not competitive with rock from Nauru, Banaba, and Christmas Island, particularly in Australia, after it was determined that fertilizer plant modifications would be nec-

Table 23.— Phosphate rock and guano: World production, by country

(Thousand metric tons)

Commodity and country[1]	1976	1977	1978[p]	1979[e]
Phosphate rock:				
Algeria	742	1,173	1,136	1,072
Australia	[r]276	450	285	--
Brazil	[r]489	650	1,023	1,500
China, mainland[e]	[r]4,000	4,000	4,500	5,000
Christmas Island (Indian Ocean)	1,033	1,186	1,400	1,250
Colombia	[r]14	8	5	6
Egypt	[r]394	472	639	650
France	[r]28	19	25	25
Germany, Federal Republic of	86	80	--	--
India	682	740	781	700
Israel	639	1,227	1,725	2,160
Jordan	1,717	1,782	2,303	2,560
Korea, North[e]	450	500	500	500
Mexico	224	285	322	350
Morocco	15,656	17,572	[2]19,713	[2]20,000
Nauru	755	1,146	1,999	2,000
Netherlands Antilles (Curacao)	54	79	81	90
Ocean Island	417	446	465	500
Peru	2	--	--	--
Philippines	12	10	1	1
Rhodesia, Southern	130	140	140	140
Senegal	1,799	1,871	1,759	1,500
South Africa, Republic of	[r]1,731	2,403	2,699	3,100
Sweden[3]	25	50	83	100
Syria	511	425	[e]750	1,000
Togo	[r]2,008	2,857	2,827	2,900
Tunisia	[r]3,301	3,615	3,712	3,800
Uganda[e]	15	5	5	5
U.S.S.R.[e]	[r]23,900	24,250	23,800	23,800
United States	[r]44,671	47,256	50,037	52,000
Venezuela	80	139	109	120
Vietnam[e]	1,500	1,500	1,800	1,000
Western Sahara	173	232	([2])	([2])
Total	[r]107,514	116,568	124,624	127,829
Guano:				
Chile	16	7	[e]7	7
Philippines	2	([4])	1	NA
Seychelles Islands[5]	6	5	6	6
Total	24	12	14	13

[e] Estimate. NA Not available. [p] Preliminary. [r] Revised.

[1] In addition to the countries listed, Belgium, Indonesia, and Tanzania may have produced small quantites of phosphate rock, and the Territory of South-West Africa (Nambia) may have produced small quantities of guano, but output is not officially reported, and available information is inadequate for formulation of reliable estimates of output levels.

[2] Production from Western Sahara area (former Spanish Sahara) included with Morocco.

[3] As reported by International Superphosphate Manufacturer's Association; official Swedish statistics show no production of phosphate rock; this material is byproduct apatite concentrate derived from iron ore.

[4] Less than 1/2 unit.

[5] Exports.

essary to use the Duchess mine rock.

Brazil.—Prior to 1977, phosphate rock production in Brazil was from the Jacupiranga mine that produced 350,000 metric tons in 1977 and the Barreiro mine at Araxá where 137,500 metric tons of 24% to 28% P_2O_5 were produced in 1977 for direct application and electric furnace feed.

A new beneficiation plant at Araxá was programed to produce 600,000 metric tons of 34% P_2O_5 concentrates in 1978. The final capacity will be 750,000 metric tons per year from the Araxá mines.

Mineração Vale do Paranaiba SA (Valep) will mine phosphate reserves at Tapira. The plans are to produce 900,000 metric tons per year of concentrates for 20 years. The plant started in August of 1978.

In early 1979, production was started at Fosfago-Fosfatos de Goras SA mine and beneficiation plant at Catalao. The production rate was 500,000 metric tons per year.

In addition to the listed projects that will be or are operational, the planned 1-million-metric-ton-per-year mine of Fertilizantes Fosfatos SA at Patos de Mines appears likely to start producing in 1981 or shortly thereafter.

China, mainland.—A large phosphate ore deposit near Kunming was identified. With reserves of 100 million tons blocked out, a flowsheet was developed to beneficiate the hard calcitic phosphate ore.

Egypt.—Two feasibility studies of the Abu Tartur phosphate rock mining project were completed. One was made by the U.S.S.R. in 1975 and another by Sofremines in 1978. The mine is located 250 kilometers west of the Nile Valley on a 300-meter-high plateau. The phosphate deposit is in an area 60 by 10 kilometers and lies under 150 meters of overburden. The deposit is flat-lying with the dip ranging from 0.5° to 1°. The deposit is 9 meters thick and averages 26% P_2O_5. The ore can be concentrated to 31% P_2O_5.

Plans are to produce 7 million tons per year of marketable phosphate rock from an estimated resource of 1 billion metric tons. The water supply will be from 30 or 40 wells, 300 to 900 meters deep, tapping three different aquifers. Power will be obtained from the main powerline from Aswän. The concentrated phosphate rock, 6 million metric tons per year designated for export, will be moved to a new port at Safaga on the Red Sea, a distance of 506 kilometers from the mine.

The ore does contain 2% to 2.5% pyrite and will make it difficult to process. The investment was estimated to be about $1 billion. The interest charges on this investment at a 10% rate will be over $14 per metric ton. Total costs will probably exceed current international phosphate rock prices.

Finland.—Because of the steady reduction in the supply of high-grade phosphate rock from the Kola region of the U.S.S.R. and replacement of this supply by lower grade north African phosphate rock, interest is increasing to develop domestic supplies of phosphate rock. Kemira tested a domestic apatite ore in a 10-ton-per-hour pilot plant at Sülinjärvi in Eastern Finland.[4]

Iran.—The Plan and Budget Organization of Iran allocated $3 million to develop phosphate deposits in the south of Iran. The rock, if produced, will supply the Shahpur chemical complex.[5]

Israel.—Negev Phosphates Ltd., was founded in 1951 to mine and process phosphate rock in the Negev Desert. A new phosphate rock mine at Nahal Zin, south of Beersheba, started producing and supplying ore to the new Zin phosphate wet beneficiation plant. Production was scheduled to be 500,000 metric tons in 1978, 1 million metric tons each in 1979 and 1980. With two production lines onstream, production will be 2 million metric tons per year in future years. In addition to the Zin plant, Negev Phosphates operates plants at Oron, Hamaktesh Hagatan, and Arad.[6]

Jordan.—Production from the Ruseifa mines near Amman was expected to stabilize at a level of 750,000 metric tons per year, production from the newer Hasa mine was scheduled to reach 2 million metric tons per year in 1978, and the total production of 2.75 million metric tons per year is forecast to expand to 5.5 million metric tons per year by 1980.[7] This may be an optimistic forecast.

A fertilizer complex at Aquaba is being planned and financed. The plant will produce sulfuric and phosphoric acid and 750,000 metric tons per year of diammonium phosphate.[8]

Jordan has expressed interest in having the U.S.S.R. develop the Shdadiya phosphate reserves estimated at 1 billion metric tons. The U.S.S.R. would design, plan, construct, and finance the mine and beneficiation plant. Jordan would pay for these services with phosphate rock.[9]

Mexico.—Contracts for a fertilizer complex 120 miles north of Acapulco on the west coast of Mexico were awarded by Fertilizantes Mexicanos, S.A. The phosphoric acid plant, a 600-metric-ton-per-day unit, will use phosphate rock from the Baha Peninsula of Mexico. A 25,000-metric-ton-per-day diammonium phosphate plant will also be constructed.[10]

Morocco.—The Office Cherifien des Phosphates have a number of projects that are planned or progressing. The black phosphate rock reserves at Youssoufia will be mined and calcined to produce a 75% BPL product for the export market. Six fluid bed calcining kilns will be added, each with a capacity of 600,000 metric tons per year. When these are installed in the 1980's, Youssoufia will have 4 million tons annual capacity of calcined black rock and the residual capability to dry 6 million tons of white (oxidized) rock that is consumed at Moroc Chemie I and II and Moroc Phosphore I at Safi.

The Ben Guirir mine located east of Youssoufia is scheduled to initially produce 1.7 million metric tons per year in 1980. By 1987, an expansion will increase capacity to at least 3.5 million metric tons per year. The ore, after sizing at the mine, will be washed at Safi for consumption at Moroc Phosphore II, Safi, as well as at the planned phosphoric acid plants at Jorf Lasfar.

The new port of Jorf Lasfar, south of Casablanca, is under construction. Five new 500,000-metric-ton-per-year phosphoric acid plants are scheduled to be constructed at Jorf Lasfar by 2000 to use ore from Ben Guirir, Sidi Hajjaj, and Khouribga.

A 5- to 6-million-ton-per-year phosphate rock mine will be developed at Sidi Hajjaj to supply ore to a washing plant that will be located at Jorf Lasfar prior to 1987.

Financing arrangements for Recette IV, an open pit mine at Khouribga, were completed in 1978. Khouribga will have three operating mines. In addition to Sidi Daoui and Mera el Arech, Recette IV will complete the near-term plans for this mining area.

Sahara.—In 1976, guerilla forces sabotaged parts of the Bu-Craa phosphate mining complex wrecking the conveyor belt in numerous locations. The single road to the Port of El Aaiun was mined, the 6,000-volt powerline was cut and many of the pylons were blown up. Under Moroccan guard, repair crews were repairing the conveyor belt and powerlines. They were guarding daily convoys of 35-ton trucks to El Aaiun. It was obviously economically impractical to truck 1,000 metric tons per day to the coast when the conveyor belt used to transport as much in 25 minutes.

It is probable that the mine will not reopen until a political settlement is reached.[11]

Senegal.—Senegal has invited tenders for a fertilizer complex. A consortium, Industrie Chimique du Senegal (ICS) was established in 1978 to plan the project. At a location near the Taiba phosphate mine a 600-metric-ton-per-day phosphoric acid plant, and an 1,800-metric-ton-per-year sulphuric acid plant were planned. The plant will consume 700,000 metric tons per year from the Taiba mine. If financial arrangements can be made in 1979, the complex will be commissioned in 1982.[12]

Togo.—The Togolese press announced on October 24, 1978, that financial arrangements were completed to expand phosphate rock production from 2.8 million metric tons per year to as much as 4 million metric tons per year after 1980. The phosphate occurrences are northest of the capital of Lomé and contain several hundred million metric tons of phosphate rock. The phosphate ore is 20 meters thick but only the top 6 meters are mined. The overburden ranges from 8 or 9 meters to a maximum of 32 meters. There are two open pit mines, Hahotoé and Kpogamé.

Tunisia.—Tunisia is planning to double phosphate rock production during the 1977-84 period. From a 3.7-million-metric-ton level in 1977, 7 million metric tons per year are planned in 1984. New washing plants were constructed to augment older washers and replace dry classification plants. New open pit mines at Kef Echfairer and the planned Djellabia mine will assure adequate ore for the beneficiation plants.

U.S.S.R.—Production of phosphate rock has remained quite stable during the past 3 years. The British Sulphur Corp., Ltd., reports 24.1, 24.2, and 24.4 million metric tons per year for 1975, 1976, and 1977, respectively. ISMA, Ltd., "The International Phosphate Industry Association," reports production in 1978 at 24.8 million metric tons.

The Soviets requested bids on a massive new superphosphoric acid plant that will produce a total of 500,000 metric tons per year from three trains. It will be located close to the Kola Peninsula's phosphate mines. It appears that production of SPA from the new Kola plant will be an additional supply to SPA imported from the Occidental Petroleum Corp. The Soviets were scheduled to receive 480,000 metric tons of P_2O_5 as SPA from Occidental in 1979 and 1 million metric tons in 1980.

TECHNOLOGY

The Bureau of Mines Tuscaloosa (Ala.) Metallurgy Research Center had a number of projects and programs in progress concerned with phosphate. The beneficiation of phosphate ores from the extension of the Bone Valley Formation in Florida that contain more than 2% MgO was started by obtaining core samples from the counties south of Polk and Hillsborough. Flotation tests on these samples showed that MgO could be removed if the sample was ground through 65 mesh, deslimed, and treated with a carbonate float. Although over 90% of the MgO was removed in the slimes or carbonate float fraction, 45% of the phosphate was lost in the end products because of the inherent softness and degradation of the collophane during milling. Sample characterization and beneficiation studies will continue with the goal of reducing MgO to less than 1.0% and maximizing P_2O_5 recoveries. Classification, scrubbing, and grinding procedures will be applied prior to flotation to attempt to produce an acceptable concentrate.

Cores were also obtained from the Hawthorn Formation in northern Florida. Some of these samples were from the Osceola National Forest. The samples were subjected to beneficiation procedures to determine recovery and product grade.

Investigations continued to determine the feasibility of producing phosphate concentrates from Florida phosphate slimes. To produce a concentrate from slimes, flotation techniques were applied to the plus 5-

micron fraction. This fraction represented about 21 weight-percent of the slimes with a recovery of 58% of the P_2O_5 in the plus 5-micron fraction.

A mobile two-stage hydrocyclone test unit was used at several Florida phosphate mine washers to obtain plus 5-micron samples for bench-scale flotation tests. The cyclones recovered 81% to 95% of the 5-micron material, however, the cyclone underflow had significant amounts of minus 5-micron material. The cyclone system was modified and the underflow was reclassified to obtain a higher concentration of the plus 5-micron material in the cyclone underflow. Cationic flotation produced improvement in grade and recovery when applied to rougher concentrates.

A program to devise technology to dewater phosphate clay slimes is a major goal of the research center. Polyethylene oxide, (PEO) was identified as an effective flocculating reagent. A continuous dewatering operation was developed using different types of equipment. The best results were obtained with a trommel screen. After conditioning with PEO, the slimes were fed to the rotating trommel for water-solids separation. A trommel, 0.5 meter in diameter by 5 meters long, was assembled for continuous testing. Tests showed that 80% to 90% of the water was removed in 20% of the trommel length. The minimum screen area required was 500 square centimeters per liter per minute of feed. The optimum mesh size was 4. Designs and specifications for a field test unit were completed by a contractor. The mobile test unit was designed, assembled, and setup in Florida for preliminary tests. A number of the plus 5-micron samples produced by the cyclones were tested in the trommels.

The percent solids in the feed ranged from 0.5 to 3.4, the percent plus 5-micron ranged from 46 to 5.9, and the PEO addition ranged from 10.5 to 0.5 kilograms per metric ton. The solid content in the dewatered product ranged from a high of 48.3% to a low of 27.9%. The flocculation dewatering tests indicate the variability of the characteristics of slimes from different plants and the variable reagent requirements for each.

Research is continuing to develop methods of reusing phosphate processing water. Surface water containing large amounts of tanin or lignin-like compounds hindered the flotation of phosphate from quartz. The tanin-lignin content of the water was reduced by the addition of phosphatic clay waste slurry followed by flocculation of the clay with PEO. The treated surface water was used in fatty acid flotation tests after the tanin-lignin concentrations were lowered. The grade of phosphate recovered by flotation was similar to that obtained using plant return water.

The Albany Metallurgy Research Center, Albany, Ore., phosphate programs were designed to develop new and improved methods for recovery of phosphate and byproduct materials from low-grade and low-quality complex phosphate deposits. Idaho and Montana phosphate samples were characterized and bench-scale tests were made to determine the effectiveness of the carbonate and silica flotation techniques on phosphatic shales and rock. Acceptable concentrate grade was achieved with all but one sample, a high dolomitic shale. Studies were made to determine the leaching characteristics of vanadium, chromium, and uranium from two samples of a low-phosphate, carbon-bearing seam of the phosphoria formation. The process of roasting with NaCl was studied to determine if there would be an improvement in metal solubilities. Salt was required to form soluble vanadium and uranium. Chrome remained essentially insoluble in all tests. With acid, 55% vanadium was extracted with water.

Flotation tests were conducted on an outcrop sample of phosphate rock from the middle Precambrian Formation, Marquette Range, Mich. Head analysis was 10.5% P_2O_5, 14% CaO, 63.8% SiO_2, and 0.26% MgO. After grinding through 325 mesh, a flotation concentrate grading 29.3% P_2O_5 with a 68% P_2O_5 recovery was produced.

The effectiveness of the carbonate-silica flotation on a high MgO phosphate sample from the Hawthorn Formation, Polk County, Fla., was tested. The sample with a head analysis of 6.3% P_2O_5, 28.9% CaO, 20.8% SiO_2, and 12.9% MgO was attritioned, ground, and deslimed. Flotation yielded a 23.5% P_2O_5 product with a recovery of 50% P_2O_5. Carbonate removal was not effective.

Studies to float calcium and magnesium phosphate minerals from Western Phosphate Rock were started. Flotation tests in the pH range of 5 to 7 were made using Hcl, H_2SO_4, or CO_2 for pH control. On unaltered phosphatic shale there was some carbonate flotation using fatty acid as a collector. Mineral locking appeared responsible for poor flotation selectivity.

Studies of the feasibility of digesting Florida land-pebble matrix to produce phosphoric acid without the customary washing and flotation beneficiation processes have continued at the Albany Metallurgy Research

Center. Stable operation of a single-tank matrix digester was achieved. The Florida matrix, ground at 50% solids, was fed to the single-tank reactor. The product acid contained 11% P_2O_5 and filtration rates of the gypsum residue were comparable to those obtained with a dry-fed system where the acid-grade product would contain 28% to 29% P_2O_5. When the single-tank reactor was operated with matrix feed in a hemihydrate crystalline mode, 42% P_2O_5 acid was produced but favorable filtration rates were not obtained with matrix feed.

There is a growing degree of skepticism about the value of restrictions or prohibitions on the use of phosphates in detergents if nothing is done to control other sources of phosphates entering into receiving waters. Independent studies in the State of Indiana, where phosphorus in detergents were prohibited since 1973, showed that the ban did not make any difference to the water quality of 15 Indiana lakes. Lakes in New York State were tested and the study seems to confirm the Indiana conclusion.[13]

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[1] Physical scientist, Section of Nonmetallic Minerals.

[2] Environmental Protection Agency. 904/9-78-026A, November 1978.

[3] Value, if sold, net selling price f.o.b. plant, or, if used, estimated value from comparable selling prices, that is, cost plus overhead and profit.

[4] European Chemical News. Mar. 25, 1977, p. 37.

[5] ———. Jan. 20, 1978, p. 9.

[6] Industrial Minerals. February 1978, pp. 12-13.

[7] European Chemical News. Nov. 10, 1978, p. 49.

[8] ———. Nov. 3, 1978.

[9] Raw Materials. Dec. 4, 1978, p. 49.

[10] The Polk County Democrat. Dec. 14, 1978, p. 5-C.

[11] World Business Weekly. V. 1, No. 7, Dec. 11-17, 1978, p. 47.

[12] European Chemical News. Nov. 10, 1978, p. 47.

[13] Phosphorus & Potassium. No. 93, January-February 1978.

Platinum-Group Metals

By James Jolly [1]

World production of platinum-group metals in 1979 was estimated at 6.66 million troy ounces, 5% higher than production in 1977 and 1978. The U.S.S.R. and the Republic of South Africa each produced about 48% of the world output in 1979 and together accounted for about 96% of the total production. Canada produced about 3%, and other countries, including the United States, about 1%. Canadian production, which normally accounts for 5% to 7% of world output, was lower in both 1978 and 1979 owing to cutbacks in nickel production in 1978 and to a long strike at the principal producers' operations.

U.S. mine production, all derived as a byproduct of copper refining, was higher in 1978-79 than in the previous 2-year period but output was insignificant compared with domestic primary needs. Refinery output, produced almost entirely from secondary materials and including both toll and nontoll metal, was 1.3 million troy ounces in 1978 and 1.4 million troy ounces in 1979. Imports and exports and their values were at record levels in 1979. Platinum and palladium in approximately equal quantities accounted for about 91% of total platinum-group metal imports. Sales of platinum-group metals to industries set successive record highs in 1978 and 1979. In 1979 sales were almost 2.8 million troy ounces; the automobile industry purchased 38% followed by the electrical industry, 21%; the chemical industry, 13%; and others, 28%.

Platinum prices continued to rise sharply in 1979, as they did in 1978, owing to continuing tight supply, inflation, strong industrial demand, and increased speculative interest, particularly after mid-1979. The high prices reduced Japanese platinum consumption in the jewelry industry such that in 1979 world demand for platinum for jewelry purposes, general industrial applications, and automotive catalysist uses, were about equal. In response to higher platinum prices and anticipated demand, South African producers announced plans to increase production and capacity.

Table 1.—Salient platinum-group metals[1] statistics

(Troy ounces)

	1975	1976	1977	1978	1979
United States:					
Mine production[2]	18,920	6,116	5,545	8,246	7,300
Value	$2,280,200	$464,527	$396,649	$759,925	$1,288,155
Refinery production:					
New metal	16,571	7,101	5,199	8,303	8,868
Secondary metal	270,101	215,355	195,219	257,191	309,022
Toll-refined metal	1,175,468	869,664	1,005,023	1,023,314	1,090,202
Total refined metal	1,462,140	1,092,120	1,205,441	1,288,808	1,408,092
Exports (except manufactured goods)	659,885	512,407	426,631	702,547	899,598
Imports for consumption	1,820,284	2,667,059	2,510,374	2,921,411	3,479,128
Stocks Dec. 31: Refiner, importer, dealer	849,210	1,085,708	1,012,812	861,411	761,282
Consumption (sales)	1,308,717	1,603,077	1,592,277	2,259,558	2,756,021
World: Production	5,713,660	[r]5,978,364	6,310,377	6,332,206	6,659,520

[r] Revised.

[1] The platinum group comprises six metals: Platinum, palladium, iridium, osmium, rhodium, and ruthenium.

[2] Recovered from platinum placers and as byproducts of copper refining.

Legislation and Government Programs.—U.S. Government inventories of platinum, palladium, and iridium were unchanged in 1978 and 1979. The quantities, in troy ounces held in the national stockpile and the goals (objectives) at year-end were as follows:

	Goal	Inventory
Platinum	1,314,000	452,645
Palladium	2,450,000	1,254,994
Iridium	97,761	16,990

Guidelines for waiver of the 1981 nitrogen oxide emission standard, based on diesel engine technology, were established.[2] Under the guidelines, a manufacturer of light duty vehicles could obtain a waiver of the nitrogen oxide standard up to a maximum of 1.5 grams per vehicle-mile during the four-model-year period beginning with model year 1981, provided certain criteria were met. Some manufacturers indicated the waiver was necessary in order to meet the 0.6-gram-per-mile particulate standard. In 1979 the Environmental Protection Agency waived the carbon monoxide (CO) standards on certain automobile engine series for 2 years, in part to reduce the economic impact on manufacturers.

DOMESTIC PRODUCTION

In 1978 and 1979 domestic mine production of platinum-group metals, all a byproduct of copper mining, was higher than in 1977 but was insignificant relative to world production. Secondary and toll-refined metal production both increased since 1977, stimulated mainly by higher platinum-group metal prices and by increased industrial usage.

The Johns-Manville Corp. (JM) continued exploration of its platinum-palladinum deposit in the Stillwater Complex, Montana. In May 1978 JM announced discovery of a high-grade platinum-palladium zone with a strike length of 18,000 feet grading 0.65 troy ounce per ton over a 7-foot width.[3]

In May 1979 JM and Chevron USA, Inc., a subsidiary of Standard Oil of California, formed a joint venture to complete exploration and evaluation of JM's Stillwater deposit. The Anaconda Company was also exploring for platinum in the Stillwater Complex, and in early 1979 announced plans to drive a 4,000-foot exploration drift to test its deposit.[4]

Amax Exploration Inc. continued to conduct environmental monitoring of ground and surface water at its Minnamax copper-nickel-platinum project near Babbitt, Minn. Field work and underground drilling were essentially complete by the fall of 1978; however, metallurgical testwork was continuing. Development of this major deposit was expected in the late 1980's.[5]

Table 2.—Platinum-group metals refined in the United States

(Troy ounces)

Year	Platinum	Palladium	Iridium	Osmium	Rhodium	Ruthenium	Total
PRIMARY METAL							
Nontoll-refined:							
1975	5,292	10,968	236	44	28	3	16,571
1976	2,748	4,025	244	45	35	4	7,101
1977	831	4,300	52	9	6	1	5,199
1978	1,081	7,222	--	--	--	--	8,303
1979	1,980	6,412	--	--	--	--	8,392
Toll-refined:							
1975	14,619	2,002	373	15	164	1	17,174
1976	8,676	1,063	355	39	95	4	10,232
1977	466	610	4	--	3	--	1,083
1978	177	1,177	--	--	--	--	1,354
1979	56	420	--	--	--	--	476

Table 2.—Platinum-group metals refined in the United States —Continued

(Troy ounces)

Year	Platinum	Palladium	Iridium	Osmium	Rhodium	Ruthenium	Total
SECONDARY METAL							
Nontoll-refined:							
1975	103,623	149,552	2,300	44	13,683	899	270,101
1976	64,901	134,747	3,921	10	8,058	3,718	215,355
1977	50,838	134,086	1,442	12	5,011	3,830	195,219
1978	75,585	166,371	1,565	3	8,266	5,401	257,191
1979	75,038	220,639	1,647	--	7,964	3,734	309,022
Toll-refined:							
1975	635,148	437,809	9,793	1,514	49,063	24,967	1,158,294
1976	494,069	311,000	6,507	1,429	34,035	12,392	859,432
1977	620,848	327,450	4,970	1,955	42,178	6,539	1,003,940
1978	630,961	344,022	6,599	667	35,914	3,797	1,021,960
1979	585,932	446,189	5,487	--	38,875	13,719	1,090,202
1978 TOTALS							
Total primary refined	1,258	8,399	--	--	--	--	9,657
Total secondary refined	706,546	510,393	8,164	670	44,180	9,198	1,279,151
Grand total refined	707,804	518,792	8,164	670	44,180	9,198	1,288,808
1979 TOTALS							
Total primary refined	2,036	6,832	--	--	--	--	8,868
Total secondary refined	660,970	666,828	7,134	--	46,839	17,453	1,399,224
Grand total refined	663,006	673,660	7,134	--	46,839	17,453	1,408,092

CONSUMPTION AND USES

Reported sales of platinum-group metals rose dramatically in 1978 and 1979 in response to improved market conditions. The automotive industry was the largest purchaser, accounting for 38% of total sales in 1979, followed by the electrical industry (21%), the chemical industry (13%), the dental-medical industry (10%), the petroleum industry (7%), the glass industry (4%) and other industries including jewelry (7%). Compared with 1977 levels, sales of the group were 42% higher in 1978 and 73% higher in 1979. Platinum accounted for about 51% of sales in 1979, followed by palladium (41%), ruthenium (4%), rhodium (3%), iridium (less than 1%), and osmium (less than 1%). In addition to sales, more than 1 million ounces of platinum-group metals in both 1978 and 1979 was recycled on a toll basis for various industries, mainly the petroleum and chemical industries.

The principal domestic uses of platinum-group metals in 1978 and 1979 were as catalysts to control automobile exhaust emissions, reforming catalysts to upgrade the octane rating of gasolines, catalysts to produce acids and organic chemicals, electrical contacts and relays primarily for use in telephone systems, bushings for glass fiber manufacture, and dental alloys for orthodonic and prosthodontic uses.

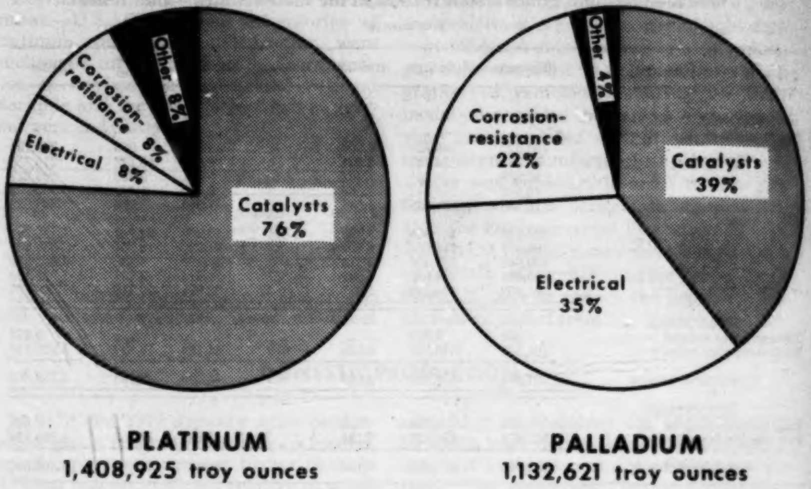

Figure 1.—Uses of platinum and palladium in 1979.

Table 3.—Platinum-group metals[1] sold to consuming industries in the United States

(Troy ounces)

Year and industry	Platinum	Palladium	Iridium	Osmium	Rhodium	Ruthenium	Total
1975	698,553	541,548	9,143	1,084	36,848	21,541	1,308,717
1976	851,105	657,062	10,117	797	40,875	43,121	1,603,077
1977	789,819	700,469	13,456	911	55,216	32,406	1,592,277
1978:							
Automotive	597,538	198,809	35	--	2,939	--	799,321
Chemical	149,696	146,352	3,938	43	19,397	16,743	336,169
Dental and medical	44,139	206,312	582	774	232	58	252,097
Electrical	106,422	286,574	8,360	--	14,329	37,222	452,907
Glass	98,094	2,757	185	--	16,606	89	117,730
Jewelry and decorative	25,751	12,570	2,218	--	9,950	315	50,804
Petroleum	108,365	18,909	--	--	281	--	127,555
Miscellaneous	66,336	45,645	1,521	--	5,907	3,566	122,975
Total	1,196,341	917,928	16,839	817	69,640	57,993	2,259,558
1979:							
Automotive	803,229	222,156	--	--	26,136	--	1,051,521
Chemical	98,600	199,743	3,705	508	11,684	49,253	363,493
Dental and medical	27,053	243,627	570	466	45	274	272,035
Electrical	115,775	392,372	8,098	--	16,923	40,021	573,189
Glass	88,594	1,729	108	--	15,376	--	105,807
Jewelry and decorative	27,712	11,766	2,014	--	7,458	308	49,258
Petroleum	170,013	24,588	2,051	--	1,223	--	197,875
Miscellaneous	77,949	36,640	755	--	4,625	22,874	142,843
Total	1,408,925	1,132,621	17,301	974	83,470	112,730	2,756,021

[1] Comprises primary and nontoll-refined secondary metals.

STOCKS

Platinum and palladium stocks held by refiners, importers, and dealers decreased in 1978 and 1979 mainly owing to strong demand and to inventory reductions due to high metal prices. Stocks of the other metals increased during the 2-year period. It should be noted that the stocks data in table 4 are partial stocks, since the Bureau of Mines does not collect inventory data from end users of the platinum-group metals, some of whom may hold sizable inventories. In addition, there were government stockpiles of platinum, palladium and iridium.

Table 4.—Refiner, importer, and dealer stocks of platinum-group metals in the United States, December 31[1]

Year	Platinum	Palladium	Iridium	Osmium	Rhodium	Ruthenium	Total
1975	420,770	335,621	18,276	627	53,847	20,069	849,210
1976	536,318	459,765	20,318	439	47,769	21,094	1,085,703
1977	438,045	475,358	15,689	420	48,392	34,908	1,012,812
1978	369,823	369,937	16,264	708	51,322	53,357	861,411
1979	305,605	323,865	18,303	1,487	49,678	62,344	761,282

[1] Includes metal in depositories of the New York Mercantile Exchange; on Dec. 29, 1978, this comprised 93,750 troy ounces of platinum and 40,000 troy ounces of palladium, and on Dec. 28, 1979, 83,950 troy ounces of platinum and 23,700 troy ounces of palladium.

PRICES

The platinum market, characterized by low demand and prices in 1977, became one of tight supply and increasing prices in 1978. The upward price trend continued in 1979, especially the dealers' price trend which was enhanced by strong speculative interest stimulated by international crises and chronic world inflation. Platinum prices in general were affected by a supply squeeze that persisted during most of the 2-year period because of higher than expected industrial requirements, record investor demand, and sharply reduced world sales of platinum by the U.S.S.R.

Palladium prices moved moderately upward in 1978 and more sharply in 1979 partly due to increased investor interest. Rhodium prices rose moderately in 1978, but in 1979, the price increased 44%, partly in response to larger purchases of the metal by the automotive industry for use in emission control catalysts. Prices for iridium, ruthenium, and osmium were essentially unchanged.

Table 5.—Monthly average producer and dealer prices[1] of platinum-group metals

(Dollars per troy ounce)

	Platinum		Palladium		Rhodium		Iridium		Ruthenium		Osmium	
	Producer	Dealer	Producer	Dealer	Producer	Dealer	Producer	Dealer	Producer	Dealer	Producer	Dealer
1977: Average	163	157	60	49	441	409	298	258	60	35	163	130
1978:												
January	188	203	60	56	453	464	300	230	60	33	150	130
February	205	224	67	64	500	508	300	244	60	32	150	130
March	215	225	70	63	500	524	300	250	60	31	150	130
April	220	213	70	60	500	515	300	245	60	32	150	130
May	220	235	70	61	500	510	300	245	60	32	150	130
June	220	244	70	59	500	509	300	241	60	34	150	130
July	236	249	70	60	500	503	300	239	60	33	150	130
August	242	264	70	62	500	495	300	238	60	33	150	130
September	250	270	70	60	518	508	300	235	60	34	150	130
October	267	298	73	74	550	566	300	241	45	34	150	130
November	284	324	80	67	550	581	300	239	45	34	150	130
December	300	340	80	70	550	599	300	238	45	35	150	130
Average	237	261	71	63	510	524	300	240	56	33	150	130

See footnotes at end of table.

Table 5.—Monthly average producer and dealer prices[1] of platinum-group metals —Continued

(Dollars per troy ounce)

	Platinum		Palladium		Rhodium		Iridium		Ruthenium		Osmium	
	Producer	Dealer	Producer	Dealer	Producer	Dealer	Producer	Dealer	Producer	Dealer	Producer	Dealer
1979:												
January	300	364	80	77	550	679	300	239	45	35	150	130
February	325	412	85	99	566	711	296	241	45	35	150	130
March	325	396	100	95	700	710	245	247	45	34	150	130
April	325	391	100	94	700	707	245	251	45	33	150	130
May	350	430	101	109	700	740	245	266	45	31	150	130
June	350	428	110	124	777	811	245	290	45	31	150	130
July	350	415	120	122	800	820	245	301	45	31	150	130
August	363	402	120	121	800	810	245	295	45	31	150	130
September	380	474	132	142	800	812	245	298	45	31	150	130
October	380	517	135	145	800	821	245	310	45	31	140	130
November	380	504	135	142	800	808	245	305	45	32	150	130
December	400	617	143	167	800	812	286	312	45	32	150	130
Average	352	445	113	120	783	770	257	280	45	32	150	130

[1] Rounded to the nearest dollar.

Source: Metals Week.

FOREIGN TRADE

In 1979 exports exceeded the record set in 1974 both in value and in total ounces. Exports valued at $200 million went mainly to Japan (40% of total value), the United Kingdom (20%), and the Federal Republic of Germany (12%). Imports and their value set successive records in 1978 and 1979. Of total imports in 1979, including estimates of metals in scrap and composite import classes, about 44% was platinum and 47% was palladium. The principal import sources were the Republic of South Africa, the U.S.S.R. and the United Kingdom.

A new tariff schedule for imported platinum-group metal alloys was to be phased in over a 7-year period beginning in 1980. Ores and unwrought and semimanufactured platinum-group metals and scrap were to remain free of any import duties.

Table 6.—U.S. exports of platinum-group metals, by country

Year and destination	Ores and concentrates (troy ounces)	Waste, scrap, and sweepings (troy ounces)	Metal not rolled (troy ounces)			Metal rolled		Total	
			Platinum	Palladium	Other platinum-group	Platinum	Other platinum-group	Troy ounces	Value (thousands)
1978:									
Argentina	60	--	50	--	1,281	--	--	1,391	$128
Australia	491	47	372	--	196	3	--	1,109	143
Belgium-Luxembourg	7,409	27,207	--	84	1,281	289	--	36,270	2,758
Brazil	835	--	6,970	1,204	159	--	979	10,147	1,612
Canada	1,126	7,281	4,716	11,045	23,974	575	2,789	51,506	8,472
Colombia	--	--	8	792	10,143	4	558	11,505	1,299
Finland	--	--	--	--	6,140	--	--	6,140	870
France	--	334	1,869	598	8,621	24	163	11,609	1,964
Germany, Federal Republic of	--	29,513	8,628	20,928	14,124	28	312	73,533	9,041
Hong Kong	2,520	--	--	--	378	8	--	2,906	81
Italy	--	--	--	--	1,721	--	--	1,721	124
Japan	1,234	2,689	112,770	54,606	33,655	18,507	1,761	225,222	44,971
Mexico	216	--	521	275	55,762	26	1,299	58,099	2,982
Netherlands	--	--	1,206	3,273	2,638	12	700	7,838	974
Norway	--	--	--	--	3,597	--	--	3,597	741
South Africa, Republic of	--	875	10	--	1,422	--	--	2,307	472
Sweden	--	638	--	--	15,313	--	--	15,951	1,343
Switzerland	--	2,616	164	--	24,097	86	--	26,963	1,709
Taiwan	--	--	1,176	--	344	--	123	1,643	388
United Kingdom	419	93,649	7,073	13,543	26,415	351	4,747	146,197	21,080
Other	87	116	522	623	4,659	27	359	6,393	538
Total	14,397	165,065	146,055	106,971	226,220	20,040	13,799	702,547	102,065
1979:									
Argentina	--	--	61	25	554	--	--	640	78
Australia	28	1	2,670	23	3,733	65	3,488	10,008	1,085
Belgium-Luxembourg	690	24,140	--	1,665	11,322	--	24	37,841	7,889
Brazil	64	112	1,711	1,192	703	16	3,018	6,816	951
Canada	693	10,528	7,515	12,816	25,522	1,533	3,789	62,396	15,199
Colombia	--	--	173	--	1,389	--	240	1,802	450

Table 6.—U.S. exports of platinum-group metals, by country —Continued

Year and destination	Ores and concentrates (troy ounces)	Waste, scrap, and sweepings (troy ounces)	Metal not rolled (troy ounces)			Metal rolled		Total	
			Platinum	Palladim	Other platinum-group	Platinum	Other platinum-group	Troy ounces	Value (thousands)
1979: —Continued									
Finland	--	--	--	--	2,574	--	--	2,574	977
France	634	67	1,834	1,391	14,677	--	150	18,753	3,136
Germany, Federal Republic of	4,889	15,605	28,912	30,038	16,319	1,021	2,092	98,876	25,428
Greece	--	--	--	1,373	3,508	--	--	4,881	453
Hong Kong	--	--	--	897	579	11	--	1,487	192
Italy	--	--	899	187	7,358	8	322	8,774	1,053
Japan	5,223	1,315	120,950	140,054	41,967	15,076	4,304	328,889	80,358
Korea, Republic of	325	--	45	1,107	474	188	--	2,139	190
Mexico	302	42	488	831	51,337	161	1,843	55,004	2,662
Netherlands	--	450	3,640	2,177	1,216	--	3,127	10,610	2,485
Norway	--	148	--	--	3,032	--	--	3,180	1,290
Singapore	410	--	132	157	562	--	--	126	102
Spain	--	--	--	--	1,910	--	--	1,910	148
South Africa, Republic of	--	1,041	--	--	5,279	--	--	6,320	1,259
Sweden	--	236	11	--	17,492	--	--	17,739	4,706
Switzerland	--	127	13,767	2,724	32,092	--	--	48,710	9,684
Taiwan	--	--	49	458	634	20	--	116	118
United Kingdom	647	121,473	3,739	14,801	6,895	160	6,569	154,284	40,334
Venezuela	16	--	7	1,336	--	--	24	1,383	133
Other	--	12	1,582	1,306	7,699	1,388	173	12,160	1,798
Total	13,921	175,297	188,185	214,558	258,827	19,647	29,163	899,598	202,157

Table 7.—U.S. imports for consumption of platinum-group metals, by country

Year and country	Unwrought (troy ounces)										
	Platinum grains and nuggets	Platinum sponge	Palladium	Iridium	Osmium	Osmiridium	Rhodium	Ruthenium	Unspecified combinations	Platinum-group metals from precious metal ores	Sweepings, waste, and scrap
1977	6,632	771,843	1,102,607	8,288	375	13,514	79,290	53,741	108,297	4,825	247,865
1978:											
Belgium-Luxembourg	--	7,187	32,337	--	--	--	1,044	--	--	--	8,904
Canada	757	4,706	19,833	52	--	--	510	18	466	--	49,002
Chile	--	--	--	--	1,608	--	--	--	--	--	--
Colombia	773	479	--	--	--	--	--	--	--	9,894	2,904
Italy	--	20,178	--	--	--	--	--	--	10,930	--	2,300
Japan	--	8,970	5,088	--	--	--	106	--	7,663	--	5,523
Mexico	--	209	--	--	--	--	53	--	--	--	106,380
Netherlands	--	3,150	4,119	--	--	--	2,495	--	16,667	--	2,282
Norway	--	4,556	6,454	--	--	--	77	--	2,711	--	--
South Africa, Republic of	19,314	885,562	488,375	26,903	200	3,778	52,971	60,291	12,559	--	445
Switzerland	--	8,387	11,097	--	--	--	750	1,000	325	--	--
U.S.S.R	1,283	5,216	474,167	--	--	--	15,467	--	15,565	--	--
United Kingdom	1,975	139,713	96,138	8,402	333	6,385	20,760	11,209	16,713	--	259
Other	1,961	7,204	18,816	579	--	--	516	1,000	300	--	10,393
Total	26,063	1,095,519	1,156,424	35,986	2,141	10,163	94,749	73,518	83,899	9,894	188,392
1979:											
Belgium-Luxembourg	--	1,778	12,578	--	--	--	725	--	896	--	15,821
Canada	32	1,512	21,780	441	--	--	959	2,000	143	--	38,719
Colombia	--	--	--	--	--	--	--	--	3,461	11,100	1,146
Italy	1,891	7,340	--	--	--	--	--	--	23	--	360
Japan	--	4,279	1,288	--	--	--	866	--	10,481	--	140
Mexico	--	--	--	--	--	--	--	--	--	--	31,862
Netherlands	--	1,451	14,178	200	--	--	919	4,000	5,958	--	1,033
Norway	--	10,842	14,657	116	--	--	699	2,116	1,480	--	2,175
South Africa, Republic of	301	1,168,374	674,190	19,237	100	--	65,157	105,118	2,675	--	882
Switzerland	3	12,205	17,693	100	--	--	250	2,000	61	--	1,189
U.S.S.R.	3,255	13,385	581,434	--	--	--	17,310	--	47,958	--	--
United Kingdom	2,750	117,485	84,641	13,009	200	7,125	15,796	9,653	11,075	--	18,945
Other	--	13,403	13,394	63	--	--	1,656	--	904	--	44,402
Total	8,232	1,352,054	1,435,808	33,166	300	7,125	104,337	124,887	85,115	11,100	156,674

Table 7.—U.S. imports for consumption of platinum-group metals, by country-Continued

Year and country	Semimanufactured (troy ounces)					Platinum-group metals in materials not elsewhere specified (troy ounces)	Total	
	Platinum	Palladium	Iridium	Rhodium	Unspecified combinations		Troy ounces	Value (thousands)
1977	44,405	49,070	501	650	59	18,502	2,510,374	273,044
1978:								
Belgium-Luxembourg	--	--	--	--	--	--	49,472	6,802
Canada	863	988	--	--	--	13,108	90,305	11,206
Chile	--	--	--	--	--	--	1,608	296
Colombia	--	--	--	--	--	500	14,550	2,775
Italy	--	--	--	--	--	--	33,408	7,127
Japan	1,049	1,198	--	--	--	--	29,597	5,957
Mexico	138	--	--	--	--	--	106,780	2,416
Netherlands	301	--	--	--	--	--	29,014	6,716
Norway	--	--	--	--	--	--	13,798	2,518
South Africa, Republic of	28,535	10,411	--	70	306	2,205	1,591,925	289,311
Switzerland	1,383	136	--	--	100	--	23,178	3,039
U.S.S.R	3,711	29,271	--	7,986	--	--	552,666	43,605
United Kingdom	16,487	24,996	--	133	--	--	343,508	63,631
Other	166	669	--	--	--	3	41,607	4,753
Total	52,633	67,669	--	8,189	406	15,816	2,921,411	450,152
1979:								
Belgium-Luxembourg	2,990	--	--	--	--	--	34,783	11,558
Canada	271	2,020	250	227	--	12,314	80,668	14,277
Colombia	--	--	--	--	--	--	15,707	3,953
Italy	--	--	--	--	--	--	7,723	3,063
Japan	14,811	1,266	--	--	--	--	35,002	13,554
Mexico	--	5	--	--	--	--	31,867	3,258
Netherlands	1	4,688	--	640	--	--	33,068	6,510
Norway	--	--	--	--	--	--	32,085	8,653
South Africa, Republic of	30,926	16,249	--	--	--	--	2,083,209	556,929
Switzerland	4,704	2,119	--	--	--	--	40,324	10,845
U.S.S.R	9,000	20,873	--	--	--	--	693,215	100,157
United Kingdom	10,134	10,361	400	3,814	134	--	305,522	91,241
Other	1,088	11,045	--	--	--	--	85,955	16,535
Total	73,925	68,626	650	4,681	134	12,314	3,479,128	840,533

Table 8.—Imports of platinum-group metals in 1978-79, by source.

(Percent of total imports)

Year and Source	Platinum	Palladium	Iridium	Osmium	Rhodium	Ruthenium	Total Imports
1978:							
South Africa, Republic of	71	37	63	29	49	78	54
U.S.S.R.	2	37	([1])	--	22	([1])	19
United Kingdom	13	9	25	48	20	15	12
Other	14	17	12	23	9	7	15
1979:							
South Africa, Republic of	78	42	47	3	58	82	60
U.S.S.R.	3	38	--	--	15	--	20
United Kingdom	9	7	42	97	18	8	9
Other	10	13	11	--	9	10	11

[1] Less than 1/2 unit.

WORLD REVIEW

World mine production of the platinum-group metals declined slightly in 1978 mainly owing to reduced Canadian production; however, in 1979 production increases in the Republic of South Africa and the U.S.S.R. resulted in record world output. In 1978 and 1979, the Republic of South Africa and the U.S.S.R. accounted for about 95% of the world output. Canada produced about 4%, and the remaining 1% was produced by the United States and other countries, principally Colombia, Japan, Yugoslavia, Finland, and Australia.

Canada.—In 1978 and 1979, platinum-group metal production was at significantly reduced levels largely owing to a cutback in nickel mining prompted by weak nickel demand, and beginning in September 1978, by a 8-month strike at Inco Ltd., the country's principal producer. By the last quarter of 1979, Inco's output had attained prestrike production levels. The value of Canadian platinum-group metals production was Can$65 million in 1978, up from Can$62 million in 1977, and reached $C56 million in 1979.

Platinum-group metals were recovered as byproducts from copper-nickel ores principally in the Sudbury and Shebandowan Districts of Ontario and the Thompson area of Manitoba. Inco Ltd. and Falconbridge Nickel Mines Ltd. were major producers. Platinum-group metals were also produced by Noranda Mines Ltd. at the Langmuir mine near Timmins, Ontario, and by Union Miniere Explorations and Mining Corp. Ltd. at its Thierry copper-nickel mine near Pickle Lake, Ontario. Owing to continuing poor results, the Langmuir mine was closed in 1978.

Rising prices for platinum increased interest in a platinum-group metal deposit in the Lac des Iles area of Ontario, owned by Boston Bay Mine Inc. The company was planning to develop a 3,000-ton-per-day open pit operation if financing could be arranged.

Japan.—Platinum demand for jewelry purposes declined in 1979 owing to higher prices; however, jewelry usage continued to be the principal consumer of platinum in Japan, accounting for more than 60% of demand. The demand pattern of platinum by industry in Japan for the 1975-79 period was as follows, in thousand troy ounces:

Industry	1975	1976	1977	1978	1979[e]
Jewelry	1,061.0	835.4	794.1	803.8	594.7
Petrochemical	41.8	35.4	32.2	48.2	45.0
Chemical	100.8	144.7	147.9	176.8	176.8
Electrical	57.9	49.0	38.6	38.6	32.2
Glass	41.8	35.4	32.2	45.0	45.0
Laboratory equipment	45.0	38.6	35.4	38.6	32.2
Other	22.8	13.2	22.1	46.1	25.7
Total	1,431.1	1,147.7	1,102.5	1,197.1	951.6

[e] Estimate.

Source: Japan Metal Journal. V. 9, No. 49, Dec. 3, 1979, p. 9.

Table 9.—Platinum-group metals: World production, by country[1]

(Troy ounces)

Country	1976	1977	1978[p]	1979[e]
Australia:				
Palladium, metal content, from nickel ore	7,950	9,581	9,500	8,500
Platinum, metal content, from nickel ore	3,158	3,697	3,500	3,000
Canada: Platinum-group metals from nickel ore	[r]416,821	465,371	346,213	[2]185,000
Colombia: Placer platinum	[r]16,779	17,300	13,939	15,000
Ethiopia: Placer platinum	145	[e]100	123	100
Finland: Platinum-group metals from copper ore[e]	[r]600	[r]640	640	720
Japan:[3]				
Palladium from nickel and copper ores	18,089	22,716	23,985	24,000
Platinum from nickel and copper ores	8,706	9,737	10,160	10,200
South Africa, Republic of: Platinum group metals from platinum ores[e] [4]	2,700,000	[r]2,870,000	2,860,000	3,200,000
U.S.S.R.: Placer platinum and platinum-group metals recovered from nickel/copper ores[e]	2,800,000	2,900,000	3,050,000	3,200,000
United States: Placer platinum and platinum-group metals from gold and copper ores	6,116	5,545	8,246	[2]7,300
Yugoslavia:				
Palladium	NA	4,951	[e]5,100	5,000
Platinum	NA	739	[e]800	700
Total	[r]5,978,364	6,310,377	6,332,206	6,659,520

[e]Estimate. [p]Preliminary. [r]Revised. NA Not available.

[1] Excludes metal refined in Norway and the United Kingdom derived from Canadian and South African ores. Also excluded is metal refined in the Federal Republic of Germany, which is believed to be derived from imported ores. Production is as follows in troy ounces: 1976—2,283; 1977—4,820 (estimate); 1978—NA, 1979—NA.

[2] Reported figure.

[3] Japanese figures do not refer to Japanese mine production, but rather represent Japanese smelter/refinery recovery from ores originating in a number of countries; this output cannot be credited to the country of origin of the ore owing to lack of data. Countries producing and exporting such ores to Japan include (but are not necessarily limited to) the Philippines, Indonesia, Canada, Australia, and Papua New Guinea.

[4] Includes osmiridium produced in gold mines.

South Africa, Republic of.—Mine output of platinum-group metals in 1978 remained at the 1977 level, but 1979 production was increased significantly owing to improved market conditions. South Africa continued to be the world's largest producer of platinum, ruthenium, and possibly rhodium and osmium. Virtually all of the country's production was mined from the Merensky Reef of the Bushveld Complex in Transvaal by three companies. Osmiridium was also recovered as a byproduct of gold mining.

Rustenburg Platinum Mines, Ltd. (RPM), a subsidiary of Rustenburg Platinum Holding Ltd. (RPH), operated three major mining sections in the western part of the complex. RPM was the world's largest producer of platinum with an estimated production of 1 million troy ounces in 1978 and 1.2 million troy ounces in 1979. RPM, which cut back production in November 1977 in response to low prices, gradually restored its production as 1978 progressed owing to improved demand and higher prices. The previously planned capital program at the Amandelbult mining section was also reinstated mainly in response to anticipated automotive catalyst requirements. Three of RPM's five production shafts had longwalling operations in place and in 1979, 37% of the tonnage mined in the Rustenburg section was produced by this method.

ATOK Platinum Mines Ltd. (APM), a RPH subsidiary acquired in 1977, operated on the eastern limb of the Merensky Reef. In 1979 stope face development along strike continued to insure the running of its mills at full capacity. Since the merger, concentrate from APM's operation has been shipped to RPM for processing.

Impala Platinum Ltd. (IPL), the world's second largest producer of platinum, produced an estimated 750,000 troy ounces of platinum in 1978 and about 830,000 troy ounces in 1979. IPL planned to spend $153 million in the next few years to expand its annual platinum mine and refinery capacity by an additional 100,000 troy ounces to 1.05 million troy ounces in order to meet maximum contract requirements of automobile manufacturers. IPL's operations continued to function well despite being divided between two countries.[4] The mines, concentrator, and smelter were in Bophuthatswana but the principal offices and refinery were in South Africa. Employee taxation and benefit arrangements, however, were complicated by the split in operations. IPL's No. 7 shaft at the Bafokeng North mine was completed, and the No. 5 Bafokeng South mine shaft, which was started in July 1978, was scheduled to be completed in early 1981.

Production of platinum-group metals by

Western Platinum Ltd. (WPL), declined 9% to 113,000 troy ounces in 1978 owing to cutbacks in production early in the year. As prices improved, WPL increased both its throughput rate and development activities. Production of platinum-group metals in 1979 totaled about 125,000 troy ounces at WPL's mine near Rustenburg. Development sampling results at the mine continued to improve, averaging 0.16 troy ounce of platinum per ton over a width of 37.4 inches.

Exploration activity in the Bushveld Complex increased in 1979. RPM was evaluating a number of areas, principally the so-called Merensky Platreef in the Potgieterust district in the northern Transvaal Province. Two U.S. companies, Sphere Mining and Development Ltd. (Utah International Inc.) and Pandora Mining Ltd. (Texasgulf Inc.), were exploring platinum-chromite deposits in the UG2 reef which lies 500 feet below the Merensky reef in the geologic section. Sphere reportedly has taken options on a large area near Boshoek, northwest of Rustenburg and was bulk sampling the deposit. Texasgulf advanced toward development of its deposit also in western Transvaal. Texasgulf sucessfully tested a new smelting technique, called the "Expanded Precessive Plasma Process," to recover the platinum-group metals from the UG2 chromite horizon of the Bushveld Complex.[7] Previous efforts to recover these metals were not economically feasible. In the process, concentrate fed through the top of the furnace is heated rapidly and smelted by a stable gas plasma at temperatures up to 10,000° C. Metal and slag are removed from the bottom of the unit. The metal is treated further by a yet undisclosed process for platinum-group metal recovery.

U.S.S.R.—The U.S.S.R. production of platinum-group metals in 1978 and 1979 was estimated to account for about 47% of the world output in the 2-year period. Small production came from gold placers in the central Urals, but most was a byproduct of nickel-copper mining in the Norilsk-Talnakh northwestern Siberia and the Petsamo-Monchegorsk region of the Kola Peninsula. Ore production in the Norilsk-Talnakh region continued to exceed processing capacity such that increasing amounts of ore were being shipped to Kola Peninsula complexes. The scale of ore shipments had been about 250,000 tons annually, but in 1978 shipments were increased, aided by ice-breaking ships to extend the shipping season. Planned mine, mill, and smelter expansions in the Norilsk region were proceeding but most were not progressing as fast as planned.[8]

TECHNOLOGY

The Bureau of Mines continued to evaluate U.S. platinum-group metal resources and to devise technology for recovery from the most promising resources. In Bureau batch-flotation testing of mineralized ore from the Stillwater Complex, Montana, platinum-group metal recoveries were better than 80% and concentrates having platinum-group metal grades of up to 30 times that of the ore were obtained.

Other Bureau work was directed toward development of improved technology for electroplating adherent coatings of the more critical platinum-group metals and alloys on various high-strength structural and process components to extend their useful life by making them less susceptible to oxidation and chemical attack.

A geochemical study of the palladium distribution in the fringe area of the tertiary porphyry copper system at Iron Canyon, Nev., led to the conclusion that although the concentrations of platinum-group metals at Iron Canyon have no economic potential by themselves, those metals should not be overlooked as a byproduct from mining in any hydrothermal environment.[9]

A new commercial process, developed by the South African National Institute of Metallurgy for the refining of rhodium, ruthenium, and iridium, was described.[10] In the process, ion exhange and solvent extraction replaced some batch processing steps in refining the three metals, reducing cost, time, and labor. The processing time reportedly was reduced from 4-6 months to 20 days, and metal purities were higher. Two companies in the Republic of South Africa were using the new process at their refineries.

Research on automotive emission control catalysts continued at a high level in order to meet the more stringent emission standards required in 1980 and 1981. Research efforts centered on reducing the platinum-rhodium ratios in catalysts to that approaching the 19 to 1 platinum-rhodium ratio found in South African ores. One company developed a two-bed converter containing a platinum-rhodium (10 to 1) three-way catalyst and a platinum-palladium (5 to 2) catalyst that proved successful in meeting 1981 standards. However, the platinum-group metal loading in the unit was 0.08 troy ounce, 60% higher than the loading used in 1979 automobile converters. Overall, the platinum-rhodium ratio in the two-bed converter was about 15 to 1. Extensive research was also underway on the development of low-density catalytic substrate materials, some of which improve converter efficiency as well as reduce converter weight.

In December 1978, the Food and Drug Administration approved the use of a platinum-based drug, cis-dichlorodiammineplatinum (II), to combat advanced stages of testicular and ovarian cancer.[11] The drug was found to be particularly effective against cancers of the reproductive system and showed promise in treating head and neck cancers as well as other types. A number of other platinum-group metal compounds of a similar type were undergoing tests to determine their effectiveness in treating various cancers. Other cancer research involving platinum-group metals utilized seeds of irradiated gold sheathed with platinum and the iridium isotope Ir-192 sheathed with steel. When implanted in malignant tissue they were found to be effective in the radiation treatment of cancerous cells.

Experiments using palladium as a catalyst in cigarette blends showed significantly reduced carcinogenicity of cigarette smoke condensate on mouse skin.[12] The catalyst, reportedly palladium in metallic form, reduced the polycyclic aromatic hydrocarbons by as much as 40% to 50%.

Programmable read-only memory fuses, which utilize platinum silicide fuse links on low-power Schottky chips were reported to have significant advantages over the nickel-chrome fuses commonly used.[13] The platinum silicide fuse, when blown, forms a gap up to 10 times longer than that formed by nickel-chrome materials, retarding regrowth of the fuse link. The reaction time is also 40 times faster.

Fuel cell research involving platinum-group metal catalysts continued to expand as a result of continuing energy problems. Two major programs were in progress in the United States. The first was the construction and evaluation of a 4.8-megawatt prototype unit that is intended to lead to the construction of large 27-megawatt stations, each sufficient for an urban locality of 20,000 people. The second program involved continued assessment and development of on-site generators of 40-kilowatt capacity for residential, commercial, and industrial applications. If these programs are successful, siginificant use of platinum can be expected; one source estimated platinum requirements as high as 165,000 troy ounces per year.[14] Fuel cell development, how they work, the function of the platinum catalyst, and factors to consider in commercial systems were reviewed.[15]

New platinum alloys with improved properties and casting characteristics were developed to increase efficiency in investment casting of platinum jewelry.[16] A 4.5% cobalt-platinum alloy was found to be superior in all aspects to the standard 4.5% copper-platinum alloy for investment casting. Another alloy, 3% gold-2% gallium-platinum, achieved a decrease in casting temperature and was also considered an acceptable replacement for the 4.5% copper-platinum alloy.

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Potash

By Richard H. Singleton[1] and James P. Searls[1]

The U.S. potash market remained relatively unchanged as demand continued for fertilizer to meet strong international requirements for U.S.-grown foodstuffs. Potash production in the United States from known reserves was static. The North American market was stable to tight as exporters met their usual markets in 1978 and strove to pick up the U.S.S.R. cut-back in exports in 1979. Worldwide, the market was balanced in 1978 but tight in 1979. In 1979, the U.S.S.R. had production and transportation problems that hindered meeting their expanding goals of exports.

Prices rose as the industry slowly recovered from overcapacity in the early seventies. In the United States, average prices for muriate, standard, coarse, and granular potash climbed from $76 per ton in 1978 to $95 per ton in 1979. Canada and the U.S.S.R., with the largest known reserves, are planning large capacity increases.

Legislation and Government Programs.—The Environmental Protection Agency (EPA) has included new potash concentrators on their list of operations due priority attention. Although present plants will not be required to meet proposed regulations, new standards will go into effect in 1982 for new plants.

The Waste Isolation Pilot Project (WIPP) in New Mexico, adjacent to the Carlsbad potash mining district, will include part of the potash reserves. In 1979, the project received $22 million fiscal year 1980 authorization to buy property, sink a development shaft, and develop drifts at the repository level to further explore the site as a national security related nuclear waste site.

Table 1.—Salient statistics on potash[1]

(Thousand metric tons and thousand dollars)

Item	1975	1976	1977	1978	1979
United States					
Production	4,151	4,016	4,241	4,326	4,271
K_2O equivalent	2,269	2,177	2,229	2,253	2,225
Sales by producers	3,465	4,184	4,241	4,356	4,549
K_2O equivalent	1,900	2,268	2,232	2,307	2,388
Value[2]	$187,900	$210,800	$206,900	$226,500	$279,200
Average value per ton	$54.22	$50.37	$48.78	$51.97	$61.38
Exports[3]	1,287	1,514	1,497	1,431	1,119
K_2O equivalent	707	857	845	809	635
Value[4]	$92,700	$91,900	$90,200	$88,600	$79,500
Imports for consumption[3] [5]	5,689	6,875	7,608	7,762	8,505
K_2O equivalent	3,445	4,168	4,605	4,707	5,165
Customs value	$267,200	$344,000	$374,000	$399,000	$520,800
Apparent consumption[6]	7,867	9,544	10,352	10,689	11,935
K_2O equivalent	4,638	5,578	5,992	6,205	6,918
Yearend producers' stocks, K_2O equivalent	562	471	467	414	251
World production, marketable K_2O equivalent	24,738	24,386	25,801	26,000	26,345

[1] Includes muriate and sulfate of potash, potassium magnesium sulfate, and some parent salts. Excludes other chemical compounds containing potassium.

[2] F.o.b. mine.

[3] Excludes potassium chemicals and mixed fertilizers.

[4] F.a.s. U.S. port.

[5] Includes nitrate of potash.

[6] Measured by sales plus imports minus exports.

DOMESTIC PRODUCTION

Domestic production was essentially unchanged for the past 3 years. In 1978-79, 82% of all production was potassium chloride and 9% was potassium sulfate. The remaining was manure salts and potassium magnesium sulfate. New Mexico accounted for 85% in 1978 and 84% in 1979 of total domestic production. Mine production in New Mexico in 1978 was 17,500,000 metric tons of crude salts with an average K_2O content of 14.2%, while production in 1979 was 17,350,000 metric tons of crude salts with an average K_2O content of 13.8%.

Seven companies produced potash in New Mexico in 1978-79, AMAX Chemical Corp. of AMAX, Inc.; Duval Corp. of Pennzoil Co., Inc.; International Minerals & Chemical Corp.; Kerr-McGee Chemical Corp. of Kerr-McGee Corp.; Mississippi Chemical Corp.; National Potash Co. of Freeport Minerals Co.; and Potash Co. of America of Ideal Basic Industries, Inc. Duval Corp. closed the North mine in 1978. In New Mexico about 70% of the mining is by undercutting, drilling, blasting, and loading while the remainder is by continuous mining methods.

In 1978-79, Texasgulf, Inc., worked an underground mine near Moab, Utah, by solution mining; Great Salt Lake Minerals & Chemicals Corp. of Gulf Resources and Chemical Corp. produced potassium sulfate as a coproduct of the Great Salt Lake brines; Kaiser Aluminum & Chemical Corp. of Kaiser Industries Corp. treated natural surface brines near Wendover.

In 1978-79, Kerr-McGee Chemical Corp. produced potash as a coproduct from Searles Lake brines in California.

There are at least two plants in the United States producing potassium sulfate from potassium chloride and sulfuric acid. Their production is not reported here since they are not mining operations.

Table 2.—Production, sales, and inventory of U.S. produced potash

(Thousand metric tons and thousand dollars)

	Production				Sold or used						Stocks, end of 6-month period			
	Gross weight		K_2O equivalent		Gross weight		K_2O equivalent		Value[1]		Gross weight		K_2O equivalent	
	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979
January-June:														
Muriate of potash, 60% K_2O minimum														
Standard	715	673	434	408	679	751	412	456	$27,400	$37,100	320	207	194	125
Coarse	346	311	212	190	386	379	236	232	19,200	22,400	168	55	103	33
Granular	403	439	244	266	427	526	259	319	21,500	31,900	104	58	63	35
Chemical	35	42	22	26	39	41	25	26	W	W	1	1	1	1
Potassium sulfate	211	212	109	109	218	119	113	103	23,100	22,500	66	52	34	27
Other potassium salts[2]	490	515	118	124	448	504	113	121	W	W	221	264	54	59
Total	2,200	2,192	1,139	1,123	2,197	2,320	1,158	1,257	113,700	139,600	880	637	449	280
July-December:														
Muriate of potash, 60% K_2O minimum														
Standard	666	674	403	410	701	711	424	432	29,400	40,500	285	170	174	103
Coarse	347	308	213	188	392	312	240	191	19,800	20,300	123	51	75	31
Granular	449	472	272	287	408	466	247	283	20,800	30,500	145	64	88	39
Chemical	38	41	24	26	39	38	25	24	W	W	1	4	(3)	2
Potassium sulfate	186	186	96	96	212	196	110	101	22,100	23,700	40	42	21	22
Other potassium salts[2]	440	399	106	95	409	425	108	100	W	W	251	237	56	54
Total	2,126	2,080	1,114	1,102	2,161	2,149	1,149	1,182	112,800	139,600	845	568	414	251
Grand total	4,326	4,271	2,253	2,225	4,358	4,549	2,307	2,388	226,500	279,200	XX	XX	XX	XX

XX Not applicable. W Withheld to avoid disclosing company proprietary data.

[1] F.o.b. mine.

[2] Includes soluble muriate, manure salts, and potassium magnesium sulfate.

[3] Less than 1/2 unit.

Table 3.—Production and sales of potash in New Mexico

(Thousand metric tons and thousand dollars)

Period	Crude salts[1] (mine production)		Marketable potassium salts				
			Production		Sold or used		
	Gross weight	K_2O equivalent	Gross weight	K_2O equivalent	Gross weight	K_2O equivalent	Value[2]
1978:							
January-June	8,770	1,250	1,861	947	1,870	972	$91,000
July-December	8,730	1,230	1,852	959	1,847	971	92,000
Total	17,500	2,480	3,713	1,906	3,717	1,943	183,000
1979:							
January-June	8,660	1,190	1,852	931	2,047	1,055	114,700
July-December	8,693	1,208	1,783	934	1,826	950	114,100
Total	17,353	2,398	3,635	1,865	3,873	2,005	228,800

[1] Sylvinite and langbeinite.
[2] F.o.b. mine.

Table 4.—Salient statistics on sulfate of potash[1]

(Thousand metric tons of K_2O and thousand dollars)

Item	1975	1976	1977	1978	1979
United States					
Production	218	211	221	205	206
Sales by producers	188	214	221	222	204
Value[2]	$35,500	$47,100	$42,400	$45,300	$46,230
Exports[3]	78	84	84	83	81
Imports	34	21	34	29	10
Value[4]	$3,100	$4,500	$6,800	[r]$6,230	$2,710
Apparent consumption[5]	144	151	171	169	133
Yearend producers' stocks	42	38	38	21	22

[r] Revised.
[1] Excluding potassium magnesium sulfate.
[2] F.o.b. mine.
[3] Export data supplied by Potash & Phosphate Institute.
[4] C.i.f. to U.S. port.
[5] Sales plus imports minus exports.

CONSUMPTION AND USES

Apparent domestic consumption of potash was 6.2 million metric tons of K_2O equivalent in 1978 and 6.9 million metric tons in 1979, an increase of 12% over that of 1978. The demand in 1978 was met by imports of 4.7 million metric tons and 1.5 million metric tons of domestic producers' sales to domestic consumers. In 1979, the demand was met by imports of 5.2 million metric tons and a 17% increase in domestic producers' sales of 1.8 million metric tons to domestic consumers.

Total sales by U.S. producers in 1978 were 2.31 million metric tons, while total sales in 1979 were 2.39 million metric tons.

The total U.S. producers potash sales (K_2O equivalent) for domestic consumption and export in 1978-79 were predominately coarse and granular grades, small quantities of soluble and chemical grades, potassium sulfate, potassium magnesium sulfate, and a negligable amount of manure salts (raw KCl-NaCl).

According to the Potash & Phosphate Institute, 300,000 metric tons and 360,000 metric tons of potash were sold in 1978 and 1979, respectively, for nonagricultural use in the United States. Of these quantities, 38% in 1978 and 37% in 1979 were of U.S. origin.

According to the U.S. Department of Agriculture, 49% of the potash used in agriculture in 1978 was applied directly, while 51% was applied directly in 1979.

According to the Potash & Phosphate Institute, U.S. sales of North American origin standard, coarse, and granular muriates moved as follows: Compared with 1977, standard muriate decreased 8% to 0.95 million metric tons in 1978 and increased 12% in 1979 to 1.07 million metric tons; in 1978 coarse muriate increased 17% to 2.30 million metric tons and in 1979 increased 7% to 2.50 million metric tons; in 1978 granular muriate increased 6% to 1.75 million metric tons and in 1979 increased 12% to 1.95 million metric tons. These figures do not include the small amounts imported from Israel, and the other minor exporters to the United States.

Apparent consumption of potassium sulfate stayed level in 1978 at 170,000 metric tons, then declined to 130,000 metric tons in 1979. According to the Potash & Phosphate Institute, consumption for agricultural purposes of both potassium sulfate and potassium magnesium sulfate from U.S. producers increased by 40% in 1979 with California, Kentucky, and Florida as the leading consuming States.

AMAX Chemical Corp. increased its potash ore reserves about 15% in 1978 to an estimated 7.9 million metric tons K_2O equivalent by noncompetitive leasing of Federal land adjoining its mine. AMAX also constructed a solar-evaporation pond to recover 10,000 tons of additional potash from mine and mill effluents. Duval Corp. terminated muriate production with the closure, at the end of May 1978, of its North mine in the Carlsbad district.

International Minerals & Chemical Corp. estimated its Carlsbad reserves to be 9.5 million metric tons of muriate and 7.7 million metric tons of langbeinite, both as K_2O equivalents. These reserves are estimated to last for 35 years, though with increasing insoluble materials in the ore. Kerr-McGee Chemical Corp. estimated its Carlsbad reserves to be 9.4 million metric tons, K_2O equivalent, all as muriate. Mississippi Chemical Corp. estimated its reserves to be 13.2 million metric tons, K_2O equivalent, all as muriate. National Potash Co.'s operation remained economically marginal. National's royalty payment was reduced from 5% to 3.5% of sales value by agreement with the U.S. Department of the Interior. Potash Co. of America estimated its reserves to be sufficient for about one decade. Texasgulf, Inc., estimated its reserves at Moab, Utah, to be sufficient for approximately one decade.

A fire at Kaiser Aluminum & Chemical Corp.'s concentrator in September 1978, suspended production until March 1979. Kaiser has started to install new evaporation ponds to replace its old ponds. The new ponds are expected to last until 1995.

Final settlement was reached at yearend 1978 on a Federal class action suit filed in 1977 by the States of Illinois, Connecticut, and Minnesota and several other potash users. The settlement, about $3 million, was made to only five users, including the States of Illinois and Minnesota, that had purchased potash directly from U.S. producers during the 1969-74 Canadian prorationing period.

Buttes Resources Co. obtained 21 2-year permits in 1978 to explore for potash on 51,000 acres of Federal land located about 15 miles northeast of Moab, Utah.

Table 5.—Sales of North American potash, by State of destination

(Metric tons of K_2O equivalent)

Destination	Agricultural potash		Nonagricultural potash	
	1978	1979	1978	1979
Alabama	95,074	121,914	42,512	66,424
Alaska	--	--	13	--
Arizona	6,500	1,595	51	2,236
Arkansas	59,997	62,642	552	367
California	62,921	67,848	7,210	9,325
Colorado	20,219	23,116	239	220
Connecticut	4,312	4,632	97	142
Delaware	33,565	31,623	26,532	29,170
Florida	118,812	162,561	717	745
Georgia	179,417	220,437	890	504
Hawaii	23,191	21,555	--	--
Idaho	17,124	14,801	27	--
Illinois	814,802	898,657	31,281	41,007
Indiana	478,558	522,627	5,845	5,645
Iowa	522,707	627,806	270	227
Kansas	59,776	54,806	2,241	2,500
Kentucky	139,743	158,811	14,898	16,113

See footnotes at end of table.

Table 5.—Sales of North American potash, by State of destination —Continued

(Metric tons of K_2O equivalent)

Destination	Agricultural potash		Nonagricultural potash	
	1978	1979	1978	1979
Louisiana	51,146	54,638	4,200	4,404
Maine	8,319	9,949	581	--
Maryland	34,903	48,442	1,308	1,444
Massachusetts	2,047	3,342	854	816
Michigan	196,758	202,314	2,728	2,916
Minnesota	493,998	484,547	401	50
Mississippi	218,625	234,288	2,909	9,294
Missouri	247,356	313,801	3,244	4,209
Montana	8,765	9,393	455	66
Nebraska	37,480	55,086	145	151
Nevada	64	68	718	797
New Hampshire	189	293	--	--
New Jersey	11,274	11,936	742	965
New Mexico	1,042	2,445	5,948	6,886
New York	69,306	74,587	53,888	49,664
North Carolina	116,244	127,173	2,224	258
North Dakota	19,645	21,567	123	79
Ohio	414,147	453,957	41,044	49,002
Oklahoma	21,718	28,266	5,522	5,310
Oregon	20,247	23,414	1,608	1,451
Pennsylvania	68,714	67,531	4,087	4,073
Rhode Island	2,186	2,131	210	133
South Carolina	83,277	85,003	297	214
South Dakota	12,000	15,752	47	23
Tennessee	130,900	157,325	62	31
Texas	172,655	199,218	24,870	36,372
Utah	1,890	6,659	1,348	661
Vermont	6,002	6,970	--	--
Virginia	64,603	65,458	779	778
Washington	39,226	38,978	3,084	2,830
West Virginia	4,950	8,577	5	28
Wisconsin	320,182	355,596	239	267
Wyoming	4,097	3,328	610	1,066
Total	5,520,673	6,177,463	297,745	359,631

Source: Potash & Phosphate Institute.

Table 6.—Sales of North American muriate of potash to U.S. customers, by grade

(Thousand metric tons of K_2O)

	1976	1977	1978	1979
Agricultural:				
Standard	1,065	1,042	954	1,067
Coarse	2,060	1,978	2,305	2,459
Granular	1,490	1,641	1,747	1,952
Soluble	360	380	387	522
Total	4,975	5,041	5,398	6,000
Nonagricultural:				
Soluble	81	102	103	118
Other	170	193	191	237
Total	251	295	294	355
Grand total	5,226	5,336	5,687	6,355

Source: Potash & Phosphate Institute.

STOCKS

Yearend 1978 producers' stocks of potash decreased slightly to the equivalent of 2.2 months of average 1978 sales. Most of this decrease was caused by inventory reductions of coarse grade muriate and of potassium sulfate.

Yearend 1979 producers' stocks of potash decreased strongly in nearly all categories to 1.4 months of average 1979 sales.

TRANSPORTATION

Canadian railroads were experimenting in 1978 with unit trains. The results were being viewed as favorable and there was a search for delivery points. Unit trains are valuable in that they decrease the turnaround time from 35 to 45 days to about 11 days. This effectively increases the number of covered hopper cars and locomotives available for potash movement.

In late 1979, Potash Corp. of Saskatchewan established a few unit train movements to the U.S. Midwest. The concept is apparently limited by the number of receiving points that are large enough to take such large quantities at one time. At that time, Seneca, Ill. and Waterloo, Iowa, were the leased receiving points.

Israel exports by freighter to the U.S. Southeast coastline. Europe exports a little potash to the Middle Atlantic States. Canada supplies by train, lake freighter, and truck to the Northern and Central United States. Carlsbad, N. Mex., ships to the Southeastern United States and exports from Houston and San Diego. Utah and California ship to the west coast.

PRICES

The average value, f.o.b. mine, for U.S. potash production of all grades in each half of 1978 was $98 per metric ton, K_2O equivalent. The average value, f.o.b. mine, in the first half of 1979 was $111 and in the second half it was $123 for a yearly average of $117. The average price for muriate, standard, coarse, and granular in 1978 was $76 per metric ton. Some individual prices were: Standard, $68; coarse, $82; and granular, $84. The average price for muriate, standard, coarse, and granular in 1979 was $95 per metric ton. Some individual prices were: Standard, $87; coarse, $101; and granular, $102.

Table 7.—Bulk prices[1] of U.S. potash, by type and grade

(Dollars per metric ton K_2O)

	1977		1978		1979	
	January-June	July-December	January-June	July-December	January-June	July-December
Muriate, 60% K_2O minimum:						
Standard	$63.44	$63.71	$66.45	$69.46	$81.33	$93.70
Coarse	78.82	80.34	81.36	82.26	96.63	106.26
Granular	81.41	77.65	82.97	84.38	96.79	107.53
All muriate[2]	71.48	70.96	75.04	76.88	89.75	100.66
Sulfate, 50% K_2O minimum	190.90	191.82	205.44	194.08	218.87	234.61

[1] Average prices, f.o.b. mine, based on sales.

[2] Excluding soluble and chemical muriates.

FOREIGN TRADE

Total U.S. exports of potash decreased 4% in 1978 to 810,000 metric tons, K_2O equivalent, compared with 1977, with a further decrease of 22% in 1979 to 600,000 metric tons. Potassium sulfates accounted for 15% of exports in 1978 and 14% in 1979.

Total U.S. imports of potash increased 2% to 4.7 million metric tons in 1978, compared with 1977, and increased 10% to 5.2 million metric tons in 1979. Of total imports, 93% were from Canada in 1978 and 94% in 1979. Israel is the second largest supplier to the United States.

Table 8.—U.S. exports of potash

	Approximate average K_2O content (percent)	1978			1979		
		Quantity (metric tons)		Value[1] (thousands)	Quantity (metric tons)		Value[1] (thousands)
		Bulk	K_2O equivalent[e]		Bulk	K_2O equivalent[e]	
Potassium chloride, all grades	61	1,126,000	687,000	$68,100	891,200	543,600	$66,050
Potassium sulfates, all grades[2]	40	305,000	122,000	20,500	227,800	91,100	13,410
Total[3]	--	1,431,000	809,000	88,600	1,119,000	634,700	79,500

[e] Estimate.

[1] Export values are f.a.s., American port.

[2] This includes potassium magnesium sulfate so the combined K_2O equivalent is estimated at 40%.

[3] Data may not add to totals shown because of independent rounding.

Source: U.S. Bureau of the Census.

Table 9.—U.S. exports of potash, by country

	Metric tons bulk						Total value[1] [3] (thousands)	
	Chloride		Potassium sulfate, all grades		Total[3]			
	1978	1979	1978	1979	1978	1979	1978	1979
Latin America:								
Argentina	2,200	1,700	2,100	3,800	4,300	5,500	$320	$420
Belize	--	360	--	9	--	370	--	45
Brazil	549,100	436,700	29,900	15,300	579,000	452,000	36,300	36,700
Chile	--	--	12,900	7,400	12,900	7,400	1,610	1,100
Colombia	39,000	19,700	18,700	3,000	57,700	22,600	3,740	1,670
Costa Rica	22,600	24,900	16,200	3,700	38,800	28,600	2,810	1,960
Dominican Republic	21,008	37,000	4,500	1,500	25,400	38,500	1,800	3,300
Ecuador	13,400	12,700	--	--	13,400	12,700	680	870
El Salvador	900	50	1,600	3,900	2,500	3,950	180	390
French West Indies	2,800	--	--	--	2,800	--	260	--
Guatemala	8,000	9,900	--	--	8,000	9,900	500	920
Guyana	2,800	750	--	--	2,800	750	350	140
Honduras	530	920	1,310	230	1,800	1,150	280	190
Jamaica	8,600	5,100	--	20	8,600	5,120	610	405
Mexico	115,700	33,500	7,600	54,100	123,300	87,600	6,580	2,700
Nicaragua	2,800	--	920	--	3,800	--	260	--
Panama	150	400	210	--	360	400	50	96
Paraguay	--	250	--	--	--	250	--	23
Peru	190	7,300	2,000	--	2,200	7,300	180	700
Trinidad	530	30	--	--	530	30	100	1
Uruguay	1,400	1,800	1,100	700	2,500	2,500	150	170
Venezuela	20		20	20	40	20	2	2
Other	170	--	50	60	220	60	13	2
Total[3]	792,000	593,000	99,100	93,700	891,000	686,700	56,800	51,900
Oceania:								
Australia	37,900	6,100	10,700	2,400	48,600	8,500	3,610	780
Canada	22,400	1,400	90,000	94,400	112,000	95,800	4,760	4,730
New Zealand	132,100	165,000	700	780	132,800	165,800	7,270	10,400
Total[3]	192,400	172,500	101,400	97,600	293,400	270,000	15,600	15,900

See footnotes at end of table.

Table 9.—U.S. exports of potash, by country —Continued

	Metric tons bulk						Total value[1] [2] (thousands)	
	Chloride		Potassium sulfate, all grades		Total[2]			
	1978	1979	1978	1979	1978	1979	1978	1979
Asia:								
Japan	74,600	55,800	66,500	35,800	141,200	91,100	$9,390	$7,700
Indonesia	60	400	--	--	60	400	2	16
Korea, Republic of	260	970	7,400	9	7,600	980	740	35
Malaysia	--	10,400	30,600	700	30,600	11,100	1,480	890
Saudi Arabia	30	740	40	--	70	740	13	36
Taiwan	21,000	--	30	50	21,000	50	1,470	4
Other	330	540	100	13	430	550	16	21
Total[2]	96,300	68,400	104,700	36,600	201,000	105,000	13,100	8,700
Europe:								
Belgium-Luxembourg	14,100	3,500	--	--	14,100	3,500	800	270
Denmark	--	26,900	--	--	--	26,900	--	1,460
France	--	10,000	80	--	80	10,000	--	200
Ireland	30,300	4,300	--	--	30,300	4,300	2,100	320
Italy	--	12,000	--	--	--	12,000	--	790
Sweden	450	--	--	--	450	--	57	--
Other	--	--	--	--	--	--	78	--
Total[2]	44,800	56,700	80	--	44,900	56,700	3,035	3,040
Africa:								
Benin	--	230	--	--	--	230	--	31
Gambia	--	--	--	65	--	65	--	2
Libya	--	180	--	--	--	180	--	4
Other	120	210	--	--	120	210	4	30
Total[2]	120	620	--	65	120	685	4	70
Grand total[2]	1,126,000	891,200	305,000	227,800	1,430,300	1,118,000	88,600	79,500

[1] F.a.s. U.S. port.
[2] Data may not add to totals shown because of independent rounding.

Table 10.—U.S. imports of potash

	Approximate average K_2O content (percent)	Quantity (metric tons)		Value (thousands)	
		Bulk	K_2O equivalent[e]	Customs	C.i.f.
1978					
Potassium chloride	61	7,623,000	4,650,000	$382,700	$497,400
Potassium sulfate	50	58,100	29,000	5,600	6,230
Potassium nitrate	45	54,000	24,300	7,750	8,770
Potassium sodium nitrate mixtures	14	25,900	3,630	2,930	3,260
Total[1]	--	7,761,000	4,707,000	399,000	515,700
1979					
Potassium chloride	61	8,428,000	5,141,000	510,800	654,300
Potassium sulfate	50	20,200	10,100	2,370	2,710
Potassium nitrate	45	19,100	8,600	3,640	3,990
Potassium sodium nitrate mixtures	14	37,700	5,300	4,000	4,660
Total[1]	--	8,505,000	5,165,000	520,800	665,600

[e] Estimate.
[1] Data may not add to totals shown because of independent rounding.

Source: U.S. Bureau of the Census.

Table 11.—U.S. imports of potash, by country

	Metric tons bulk										Total value (thousands)			
	Chloride		Sulfate		Nitrate		Potassium sodium nitrate		Total		Customs		C.i.f.	
	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979
Belgium-Luxembourg	--	--	13,000	7,500	--	--	--	--	13,000	7,500	$1,230	$840	$1,350	$980
Canada	7,180,000	8,026,500	5	240	230	230	620	1,420	7,181,000	8,028,400	359,100	482,100	469,700	622,300
Chile	--	--	--	--	1,800	--	25,200	36,200	27,100	36,200	3,080	3,720	3,440	4,330
El Salvador	--	22	--	--	--	--	--	--	--	22	--	1	--	2
France	--	--	17,700	3,200	--	--	--	--	17,700	3,200	1,890	400	2,100	460
German Democratic Republic	30,900	68,000	--	--	4,000	--	--	--	34,900	68,800	1,510	3,880	2,100	4,500
Germany, Federal Republic of	6,600	12,400	20,200	9,200	54	--	--	--	26,900	21,600	3,070	2,010	3,110	2,440
Israel	332,000	285,100	7,200	--	47,900	18,900	--	--	387,500	304,000	25,730	25,640	29,500	28,110
Japan	--	--	--	--	--	--	46	110	46	110	8	22	11	31
Mexico	--	91	--	--	--	--	--	--	--	91	--	6	--	8
Norway	8,800	--	--	--	--	--	--	--	8,800	--	300	--	610	--
Spain	30,200	20,500	--	--	--	--	--	--	30,200	20,500	1,500	1,420	1,870	1,540
U.S.S.R	29,300	12,100	--	--	--	--	--	--	29,300	12,100	1,270	605	1,530	830
Yemen	4,900	2,300	--	--	--	--	--	--	4,900	2,300	220	140	290	180
Total[1]	7,623,000	8,428,000	58,100	20,100	54,000	19,100	25,900	37,700	7,761,000	8,505,000	399,000	520,800	515,611	665,700

[1] Data may not add to totals shown because of independent rounding.

Source: U.S. Bureau of the Census.

WORLD REVIEW

For 1978, Western World output reached 14.3 million metric tons K_2O equivalent while East Europe's and the U.S.S.R.'s output was estimated at 11.7 million metric tons K_2O equivalent. Potash production in North America in 1978 was 8.4 million metric tons of K_2O equivalent. Total overseas exports for North America increased 18% to 2.37 million metric tons. Areas receiving these exports in decreasing order were Asia, mainly Japan; Latin America, mainly Brazil; Oceania, Western Europe, and Africa. Exports to Asia increased 19% compared with 1977.

Total exports for 1978 from the two East European producing countries, the U.S.S.R. and the German Democratic Republic, remained at 5.1 million metric tons. Areas receiving these exports were other East European countries, Western Europe, Asia, Latin America, and others.

Total potash production in Western Europe, Israel, and the People's Republic of the Congo, increased 6% in 1978 to 5.8 million metric tons. Total exports from West European primary producing countries, including Israel, increased 8% to 2.8 million metric tons. Areas receiving these exports were Western Europe, Asia, Africa, North America, Latin America, and others.

Total world shipments in 1978 to nonproducing countries, including Italy and the United Kingdom, increased 7% to 9.7 million metric tons; receiving areas were Eastern Europe, mainly Poland, 31%; Western Europe, 24%; Asia, mainly Japan and India, 23%; Latin America, mainly Brazil, 15%; Africa, mainly South Africa, 4%; and Oceania, 3%. Imports into Brazil, the market-economy world's largest nonproducing importer, increased 5% to 980,000 metric tons of K_2O. Imports into Japan, the second largest nonproducing importer in the market-economy world, also increased 5% to 760,000 metric tons.

Total 1978 exports of potassium sulfate from European producing countries increased 4% to 560,000 tons; of this, 34% was shipped to nonproducing West European countries.

For 1979, world output was estimated to be about 26 million metric tons, up about 1%. Market-economy world production increased to an estimated 15.3 million metric tons while East Europe's and the U.S.S.R.'s production declined to an estimated 11 million metric tons.

North American potash production for 1979 increased 5% to 8.8 million metric tons. Total overseas exports increased 4% to 2.47 million metric tons. Areas receiving these exports were: Asia, mainly Japan, 46%; Latin America, mainly Brazil, 32%; Oceania, 17%; Europe, 3%; and Africa, 2%.

Brazil.—Petrobrás Mineração S.A. announced plans to build a mine-mill complex at the Taquari-Vassouras deposit in Sergipe in northeastern Brazil. Initial production of muriate of potash, an amount equivalent to 300,000 metric tons of K_2O, was planned by 1983; this would meet only about one-quarter of Brazilian demand projected for that time. Total projected investment was $150 million. The operation would be owned mainly, 82%, by the Federal Government. A $115 million loan for construction of the complex was arranged provisionally with the Government of France; commitment was subject to the findings of a technical-economic feasibility study by a French firm, Compagnie de Potasse d'Alsace, scheduled to be completed in April 1979. The deposit is a high-grade sylvinite 400 to 1,000 meters below the surface; however, it is irregular and mining problems are expected. Phase II plans for this deposit call for increasing production by 600,000 tons K_2O equivalent. There is no clear date for this expansion but it will occur at both the Taquari-Vassouras and the Santa Rosa de Lima deposits. Brazil imported 989,500 metric tons of K_2O (7% of world trade) in 1978. Stocks were put at 500,000 metric tons at the end of 1978. Ninety-six percent of the imports came as muriate of potash. Two percent was potassium sulfate and the rest was potassium nitrate.

Canada.—Canadian exports to Asia and Oceania were upset in October 1979 by accidental damage to the railroad bridge in Vancouver, British Columbia, that connects the Canadian National Railroad with the Vancouver Wharves terminal. One company, Kalium Chemicals Ltd. declared "force majeau." Canpotex Ltd. and Potash Co. of America are continuing their shipments but with difficulty. The bridge is expected to be repaired by March of 1980. About five-sixths of Canadian consumption continued to be in the Provinces of Ontario and Quebec.

In 1978, the Government of the Province of Saskatchewan continued acquisition of that Province's potash industry by purchase of portions of two U.S.-owned mining operations. On January 31, the Government acquired Amax Potash Ltd.'s reserves (50 to 70 million tons of K_2O equivalent) and its service contract with International Minerals & Chemical Corp. (Canada) Ltd. (IMCC) to mine and beneficiate potash. On April 20, the Government purchased 60% of the mine and plant owned by APM Operator's Ltd. The remaining 40% was owned by Texasgulf, Inc., about one-third of which was owned by the Canadian Federal Government. These two acquisitions gave the Province control of five separate operations with a total capacity equivalent to about 2.9 million metric tons or about 39% of the Province's total capacity. Nearly half, about 3.5 million metric tons, of Saskatchewan's potash industry was still owned by U.S. private companies at yearend. The Government stated that it has no further plans to seek other acquisitions. The Potash Corp. of Saskatchewan (PCS), a crown corporation that operates the Government-owned units, is now the largest potash producer in North America. Total Canadian capacity at yearend was about 7.6 million metric tons.

PCS announced plans to increase, by 1981, its total annual capacity by 30% to about 3.8 million metric tons. Expansion of mining, hoisting, and milling capacities began at each of its three wholly-owned facilities, PCS Cory Ltd., PCS Rocanville Ltd., and PCS Lanigan Ltd. No expansions of its two partially owned facilities were announced. The Cory expansion and the first phase of the Rocanville expansion were completed during 1979. Hoisting capacities at these plants were increased by doubling hoist speed. The second and final phase of the Rocanville expansion, scheduled for 1981, would boost annual capacity of this facility to 1.1 million metric tons making it the largest PCS unit. Lanigan was closed for 5 months beginning in June 1979 as part of a 50% increase in annual capacity to 830,000 metric tons, scheduled for completion by yearend 1980.

Saskatchewan's controversial Provincial reserves tax was upheld by a decision of the Court of Queen's Bench in Regina, Saskatchewan, on November 17, 1978. This tax was based on reserves, productive capacity, and selling price. Private producers had argued that the levy was essentially a tax on production and that such indirect taxes could be collected only by the Federal Government. The Court contended that it was primarily a direct tax on property.

The Supreme Court of Canada ruled on October 3, 1978, that prorationing by the Saskatchewan Government of potash production in that Province is unconstitutional. This prorationing had been authorized by Provincial legislation in 1969. Actual prorationing had been terminated in 1973. CCP Industries, a private producer of potash in Saskatchewan, had, in 1975, been awarded Can$1.5 million in damages by the Court of Queen's Bench in Regina. It had been the original intention of CCP to deliver most of its product to a captive U.S. market. In early 1977, a Court of Appeals in Saskatchewan had overturned the lower court's ruling that the prorationing legislation was unconstitutional. CCP then had appealed to the Supreme Court. The Supreme Court's October ruling restored the 1975 ruling of the Court of Queen's Bench. CCP's claim for Can$13 million from lost sales was disallowed, however, by the Supreme Court on the basis that CCP's claimed "intimidation" by the Provincial Government was not an unlawful act.

In 1979 a "resource payment agreement" was worked out in Saskatchewan to replace the reserves tax. There is a production charge of Can$6 per short ton for the first 300,000 short tons and Can$7.50 for production above that. There is also a graduated tax on earning, allowing for an annual deduction of 4.5% of operating costs and an annual 10% write-off on new investment for major facilities.

Potash Co. of America began sinking the 2,400-foot shaft for its potash mine in New Brunswick. The shaft was completed in the fall of 1979. The plan indicated that mill construction and sinking of a second shaft would begin after the structure of the deposit is confirmed. Estimated reserves were increased as a result of further exploration conducted during 1978.

On March 29, 1978, the Provincial Government of New Brunswick granted IMCC a mining lease to remove potash from a 21,000-acre area around Salt Springs near Sussex, New Brunswick. IMCC stated that further drilling and analysis of mining techniques were required before economic feasibility could be determined. The uncertainty was caused by geologic folding of the potash bed and a minimum thickness requirement, yet to be determined, of a halite bed that covered the potash. Reserves had been defined by IMCC as 11 to 29 million metric tons, based on seven drill holes. The high-grade sylvinite bed, with an average K_2O content of 29%, is at a depth of 2,000 to 3,400 feet. In 1979, IMCC sold the deposit to Denison Mines Ltd. who is continuing plans to develop the deposit.

Table 12.—Salient statistics on Canadian potash

(Thousand metric tons of K_2O equivalent)

	1977	1978	1979
Production[1]	6,089	6,124	6,715
Domestic sales by domestic producers[1]	249	370	379
Exports:			
United States[1]	[r]4,198	4,498	4,931
Overseas[1]	1,232	1,596	1,846
Imports for consumption[e][2]	31	39	29
Domestic consumption[3]	259	409	408
Yearend producers' stocks[1]	1,183	832	378

[e] Estimate. [r] Revised.

[1] Data supplied by the Potash & Phosphate Institute.

[2] From U.S. Bureau of the Census export data, assumed 30% K_2O equivalent for the mixture of potassium sulfate and potassium-magnesium sulfate and 61% K_2O equivalent for potassium chloride according to the estimated relative tonnages to Canada.

[3] Domestic sales by domestic producers plus imports.

Chevron Oil reports a show of potash in an exploratory well on Cape Briton Island, Nova Scotia, near Port Hawkesburg.

China, Mainland.—There is currently no information on China's potash reserves or production. Currently Chinese production is limited to a product from a lake in Qinghai Province. They have expressed interest in visiting the Great Salt Lake potash operation in the United States. There is also a report of the discovery of potash at Jianpching in the Yunnan Province.

France.—Production of potash in 1978 increased 14% to 1.80 million metric tons of K_2O. Yearend producers' inventories remained low, at near 80,000 tons of K_2O. The total work force was nearly halved, to about 6,000, to improve productivity.

Construction of an underground repository near Mulhouse for waste brines from the Alsatian potash industry was delayed because of local fears that underground water supplies might be polluted. In the meantime, legal action by a Dutch environmentalist group plus three market gardeners against the French mines for polluting the Rhine River with salt, after 4 years of procedural arguments, came to trial on October 23, 1978, in a Rotterdam court. The Dutch maintained that French mines were responsible for 40% of the pollution of Rhine water entering the Netherlands. The French mines claimed that this figure was only 7%. No out-of-court settlement was expected. By the end of 1979 there had still been no settlement as the matter was not brought up before the French Assembly.

German Democratic Republic.—Production increased to 3.3 million metric tons of K_2O in 1978 and to 3.4 million metric tons in 1979. The Government awarded a contract to a West German firm to construct a 2,600-ton-per-day granulation plant at the Zielitz mine, the country's largest. Plant design was based on U.S. technology. An agreement signed in 1979 may bring 250,000 to 300,000 tons per year of product from this mine to the U.S. east coast. Construction was scheduled to begin early in 1979 and to be completed in 1981. The German Democratic Republic's potash granulation capacity was somewhat under 500,000 tons per year in 1978.

Germany, Federal Republic of.—Production increased 6% to 2.47 million metric tons of K_2O equivalent in 1978. Domestic consumption decreased about 10% to approximately 1.3 million tons of K_2O, mainly because of unusually bad spring weather. Approximately 90% of domestic consumption was in agriculture. Increased exports more than compensated for slow domestic sales and producers' stocks decreased by about 80,000 tons to approximately 160,000 tons of K_2O.

Israel.—Output of K_2O was affected by a strike effecting both production and deliveries that began in late November and was still in effect at yearend 1978. Delivery commitments were partially met by purchases of potash from Eastern Europe. Despite the strike, exports of Israeli potash reportedly remained at about the same level as 1977. Exports accounted for 84% of total sales in 1978. Total yearend inventories decreased 28% to 280,000 tons of K_2O.

In 1979, Israeli Dead Sea Works, Ltd. announced plans to further expand capacity to 1.3 million metric tons of K_2O equivalent by 1985. This increased capacity of 550,000 tons per year will be produced by a two-stage, energy efficient, crystallization technique. Most of the increase was to be in the form of granular muriate, reportedly directed toward the U.S. market.

Italy.—Production, all standard-grade sulfate, increased to about 249,000 metric tons of K_2O in 1978. Mine output had fallen below refinery capacity and a firm funding commitment to develop a proposed mine, based on a deposit near Milena, was being sought. Sales were being increasingly oriented toward the export market. However, Italy remained a net importer of potash; about 300,000 metric tons of K_2O equivalent, as muriate, were imported in 1978. The new mine at Milena was developed in 1979 to replace a depleted mine but capacity set by the refineries remains unchanged.

Jordan.—Full capacity operation, 700,000 metric tons of K_2O per year, by the Arab Potash Co., of the plant was scheduled for 1982. Owners of the Arab Potash Co. were the Jordanian Government, 51%; the Arab Mining Co., 44%; and the Libyan Government, 5%. The bulk of the financing was secured during 1978. Total projected capitalization was about $425 million; about 45% was to be met by equity capital and the remainder by loans. Five-year marketing contracts were established with three world-marketing companies beginning in 1982; these companies were to sell in three respective world areas in the approximate proportions: Asia, 50%; the Americas, 30%; and Western Europe, 20%.

Mexico.—A pilot plant was operated in 1978 for extraction of potash from effluent brines from the geothermal powerplant at Cerro Prieto, Baja, Californes Norte, south of Mexicali. Sufficient data for a definitive decision to build a 50,000-ton-per-year K_2O commercial plant was expected to be available in 1979. Mexican imports more than doubled to about 90,000 metric tons of K_2O equivalent in 1978, mostly as muriate.

Spain.—Spanish production in 1978 continued at about 560,000 metric tons of K_2O. Potassas de Navarra, S.A., the Government-owned plant, opened a new sylvinite mine in 1978 increasing mine production by 25% to 2.5 million tons per year of hoisted ore. Potassas de Navarra also announced plans to modernize and remove process flow restrictions in its refinery. These plans included installation of compacting equipment for production of granular muriate. Union Explosivos Rio Tinto, S.A. hoped to increase the capacities of its two Catalonian mines, Llobregat and Cardona, from 300,000 to 350,000 metric tons per year K_2O equivalent by the end of 1979.

Thailand.—Thailand has discovered potash deposits on the Korat Plateau in northwest Thailand and has asked for help from experienced potash companies in exploring and developing the deposits. The discovery was made by the Thai's Department of Mineral Resources in collaboration with the U.S. Geological Survey. The deposit is said to be carnelite and sylvinite, and possibly the same size as that of Saskatchewan.

U.S.S.R.—Estimated production remained at approximately 8 million metric tons of K_2O; a shortfall of about 1.0 million tons of K_2O occurred mainly in the Uralkali Combine where two plants built 4 years earlier operated reportedly at only two-thirds capacity. The dissolution-recrystallization method may be used in this 1.5-million-ton-per-year K_2O plant. Construction of the other two large complexes in the Uralkali combine continued; completion of these would reportedly double Uralkali capacity. The final mine shaft was sunk in the Berezniki 4 unit; construction of this unit was reportedly behind that of Novosolikamsk, the other Uralkali unit being built. A new plant, Soligorsk 4 in the Byeloruskali Combine, began operation at about 50% capacity at yearend 1978.

U.S.S.R. domestic consumption is reported to be 4.9 million metric tons of K_2O equivalent for 1978. Eighteen percent of U.S.S.R. exports went to West Europe, 65% went to East Europe, 5% went to Latin America, 11% went to Asia, and 1% went to Oceania with a smaller amount coming to the United States. Exports were inhibited by continuing rail transport difficulties and limited port handling facilities. The port of Ventspils was closed for several months in 1978 because of a modernization program involving construction of new facilities. U.S.S.R. production for 1979 is estimated to be 7.5 million metric tons of K_2O equivalent.

United Kingdom.—Average output of the Boulby mine, the country's only potash producer, nearly doubled to about 150,000 tons of K_2O equivalent in 1978. Monthly output was nearly twice this annual rate during March and April and again near the end of the year. A break-even point was reportedly nearly reached during these brief periods. About one-third of the product was exported and most of the balance was consumed domestically.

In 1979, Imperial Chemical Industries sold its 50% holding to Anglo American Corp. (formerly 12.5% holding) and Charter Consolidated (formerly 37.5% holding). The plant is struggling to produce at the 500,000-ton-per-year KCl level. The plant will be reevaluated for closure again in February 1980. One problem with closure is the cost of returning the site, located in a national park, to its original condition.

Whitby Potash Ltd., a solution mine in the North York Moors National Park, has been dropped. The project faced rising costs and environmental problems.

Table 13.—Marketable potash: World production by country

(Thousand metric tons of K_2O equivalent)

Country[1]	1976	1977	1978[p]	1979[e]
Canada	4,996	6,089	6,124	6,600
Chile	15	[e]16	[e]17	15
China, Mainland[e2]	[r]150	[r]150	150	150
Congo	254	81	--	--
France	[r]1,603	1,578	1,795	1,850
German Democratic Republic	3,161	3,229	3,323	3,400
Germany, Federal Republic of	2,036	2,341	2,470	2,600
Israel	[r]680	719	732	725
Italy	[r]330	150	249	240
Spain	[r]630	563	[e]558	590
U.S.S.R.	8,310	8,347	8,193	7,500
United Kingdom	[r]41	81	136	450
United States	2,177	2,229	2,253	[3]2,225
Total	24,386	25,801	26,000	26,345

[e]Estimate. [p]Preliminary. [r]Revised.

[1]In addition to the countries listed, Australia apparently produced small quantities of marketable potash during 1976-78, but output was not reported quantitatively and general information was inadequate for the formulation of reliable estimates of output levels.

[2]Series revised to conform with changes made by data source (British Sulphur Corp., Ltd, Statistical Supplement No. 20, January-February 1980, London, p. 12). Data provided in this edition is on a calendar year basis.

[3]Reported figure.

TECHNOLOGY

The Bureau of Mines has published a report[2] on producing muriate of potash from lower grade ores with higher insoluble materials content. This is done in anticipation of declining ore grades in the Carlsbad area. The study was concerned with 13% K_2O grade of ore with 5% insoluble materials content. The insoluble materials are floated in two stages then the potash is floated in two stages of flotation. These bench tests indicate 60% K_2O at 77% recovery.

Kali und Salz AG of the Federal Republic of Germany received a Canadian patent[3] for electrostatic separation of sylvite (KCl) from halite (NaCl). The salt is ground, then dropped through two stages of separation. The first, up to 1.2 meters long, separate the potassium fraction. The process possibly may be performed in the mine to solve the halite disposal problem and increase the productivity of the hoist.

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[1] Physical scientist, Section of Nonmetallic Minerals.

[2] Thompson, P., and J. L. Huiatt. Bench-Scale Flotation of Insoluble Slimes From Potash Ore. BuMines RI 8384, 1979.

[3] Singlewald, A., G. Fricke, I. Geisler, and R. Knappe (assigned to Kali und Salz A.G., Kassel, Federal Republic of Germany). Title unknown. Can. Pat. 1,066,230, Nov. 13, 1979.

Pumice and Volcanic Cinder

By Arthur C. Meisinger[1]

U.S. production of pumice and volcanic cinder (including pumicite and scoria) in 1979 was 4.4 million tons valued at $16 million, or 7% less in quantity but 10% more in value than the 1978 record output of 4.8 million tons and $14.5 million, respectively. The 1979 output came from 306 operations in 11 States, compared with 320 operations in 13 States in 1978. Four States, Arizona, California, Nevada, and Oregon, accounted for about three-quarters, or 3.3 million tons of the amount sold and used by producers in 1979, compared with 3.6 million tons in 1978.

U.S. consumption of volcanic cinder and scoria in 1979 decreased 9% in quantity but increased 14% in value compared with that of 1978. Road construction and maintenance, the major use of volcanic cinder and scoria, accounted for 57% of the total output in 1979, compared with 60% in 1978.

U.S. consumption (excluding imports) of pumice and pumicite also declined in 1979, but the value of material sold and used established a new high of $5 million that exceeded the 1978 record of $4.8 million by 4%. The principal end use of pumice and pumicite continued to be in concrete admixture and aggregate; however, this decreased to 1.09 million tons in 1979, compared with 1.15 million tons in 1978.

The weighted average value of pumice and related volcanic materials in 1979 increased 19% to $3.62 per ton from $3.04 per ton in 1978. With few exceptions, average values per ton for the principal end uses in 1979 were higher than those of 1978.

Pumice imported for consumption in 1979 decreased significantly (71%) in quantity from that in 1978, primarily owing to structural damage of loading and docking facilities on Yali Island, Greece, in late 1978 that resulted in a year-long stoppage of pumice shipments to the United States.

Table 1.—Salient pumice and volcanic cinder statistics

(Thousand short tons and thousand dollars)

	1975	1976	1977	1978	1979
United States: Sold and used by producers:					
Pumice and pumicite	790	906	1,178	1,208	1,173
Value[1]	$3,493	$3,830	$4,625	$4,836	$5,008
Average value per ton	$4.42	$4.23	$3.93	$4.00	$4.27
Volcanic cinder and scoria	3,102	3,228	2,831	3,549	3,241
Value[1]	$7,710	$6,636	$7,340	$9,619	$10,953
Average value per ton	$2.49	$2.06	$2.59	$2.71	$3.38
Exports	1	1	2	^{e}2	^{e}2
Imports for consumption	145	81	253	216	62
World: Production, pumice and related volcanic materials	^{r}16,200	^{r}16,800	18,000	^{p}19,600	^{e}19,500

^{e}Estimate. ^{p}Preliminary. ^{r}Revised.

[1] Values f.o.b. mine and/or mill.

DOMESTIC PRODUCTION

U.S. output of pumice, pumicite, volcanic cinder, and scoria decreased 7% in quantity but increased 10% in value in 1979, compared with the record highs of 4.8 million tons and $14.5 million established in 1978. Domestic output came from 73 individuals, firms, and governmental agencies producing from 306 operations in 11 States, compared with 81 producers and 320 operations in 13 States in 1978, and 92 producers and 253 operations in 12 States in 1977. California led all producing States in 1979 in number of active operations with 140, followed by Oregon with 62 and Arizona with 41. The combined quantity of pumice and related volcanic materials produced in Arizona, California, Nevada, and Oregon was 3.3 million tons, or 74% of the national total compared with 3.6 million tons (75%) in 1978 and 3.0 million tons (75%) in 1977.

Production of volcanic cinder and scoria decreased 9% in quantity but increased 14% in value compared with that of 1978. Output of pumice and pumicite in 1979 decreased 3% in quantity from the record high of 1.2 million tons in 1978; however, value of production increased 4% to $5 million from the record high of $4.8 million set in 1978. Production of all volcanic materials increased significantly in 1978 compared with 1977 totals.

Of the total U.S. output (3.2 million tons) of volcanic cinder and scoria in 1979, operations (primarily from U.S. Forest Service pits) in Arizona, California, New Mexico, and Oregon accounted for 2.7 million tons or 84%, compared with 3.2 million tons (91%) in 1978 and 2.4 million tons (86%) in 1977.

CONSUMPTION AND USES

Apparent U.S. consumption (sold or used plus imports minus exports) of pumice, pumicite, volcanic cinder, and scoria totaled 4.5 million tons in 1979, a decrease of nearly 500,000 tons from that in 1978.

U.S. consumption of domestic production by principal end use for pumice and pumicite (table 3) in 1979 declined 3% in quantity from that in 1978, but increased 4% in value. Pumice and pumicite used for concrete admixture and aggregate (the major end use) declined slightly from the quantity used in 1978; however, the quantities used in abrasives and in landscaping increased significantly in 1979.

Of the end uses shown in table 4 for volcanic cinder and scoria, only the quantity used in concrete continued to increase in 1979 after increasing in 1978.

Table 2.—Pumice, pumicite, volcanic cinder, and scoria sold and used by producers in the United States, by State

(Thousand short tons and thousand dollars)

State	1977		1978		1979	
	Quantity	Value	Quantity	Value	Quantity	Value
Arizona	621	1,226	1,135	3,130	940	2,367
California	636	3,838	831	3,458	800	3,973
Hawaii	260	574	272	658	359	1,240
Montana	5	7	--	--	--	--
Nevada	656	1,154	706	1,282	W	W
New Mexico	457	1,835	631	2,706	604	3,550
Oklahoma	1	W	1	W	1	W
Oregon	1,083	2,429	915	2,016	781	1,644
Utah	W	W	28	270	28	280
Washington	W	W	50	63	--	--
Wyoming	--	--	7	W	--	--
Other States[1]	290	902	181	872	901	2,907
Total	4,009	11,965	4,757	14,455	4,414	15,961
American Samoa	1	10	4	24	2	15

W Withheld to avoid disclosing company proprietary data; included with "Other States."

[1] Colorado, Idaho, Kansas (1978), Nevada (1979), Oklahoma (value only), Utah (1977), Washington (1977), and Wyoming (1978 value only).

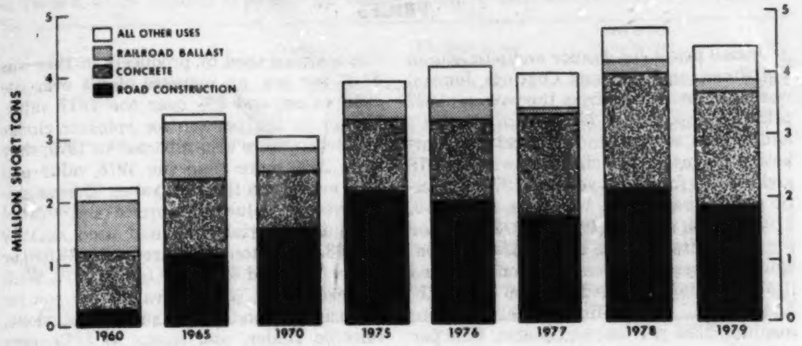

Figure 1.—Pumice and related volcanic materials sold and used by producers in the United States, by use.

Table 3.—Pumice and pumicite sold and used by producers in the United States, by use

(Thousand short tons and thousand dollars)

Use	1977		1978		1979	
	Quantity	Value	Quantity	Value	Quantity	Value
Abrasives (includes cleaning and scouring compounds)	26	749	15	448	28	649
Concrete admixture and concrete aggregate	1,094	2,612	1,153	2,968	1,094	3,254
Landscaping	27	590	10	484	25	196
Other uses[1]	31	674	30	936	26	909
Total	1,178	4,625	1,208	4,836	1,173	5,008

[1] Includes decorative building block, heat-or-cold insulating medium, pesticide carriers, soil conditioners, roofing granules, and miscellaneous industrial uses.

Table 4.—Volcanic cinder and scoria sold and used by producers in the United States, by use

(Thousand short tons and thousand dollars)

Use	1977		1978		1979	
	Quantity	Value	Quantity	Value	Quantity	Value
Concrete admixture and aggregate	565	1,875	726	2,289	744	3,066
Landscaping	293	1,263	352	3,253	184	2,538
Railroad ballast	94	192	199	405	193	400
Road construction (includes ice control and maintenance)	1,722	2,990	2,139	3,176	1,848	3,831
Other uses[1]	157	1,020	133	496	272	1,118
Total	2,831	7,340	3,549	9,619	3,241	10,953

[1] Includes absorbents, asphalt mix, roofing granules, and miscellaneous uses.

PRICES

Quoted prices for pumice and pumicite in the American Paint and Coatings Journal remained unchanged from the yearend 1977 prices. Prices quoted for pumice (domestic and foreign sources) in Chemical and Marketing Reporter were changed twice in 1978 and were as follows at yearend 1979: Domestic grades, bagged, in 1-ton lots, fine, 4F-0, $205 per ton; medium, 0-1/2 - 1-1/2, $225 per ton; and coarse, 2-extra coarse, $205 per ton. Quoted prices at yearend 1979 on imported (Italian) pumice, bagged in 1-ton lots, f.o.b. East Coast, follow: fines, $200 per ton; medium, $285 per ton; and coarse, $250 per ton.

The average value for pumice and pumicite sold and used by producers in 1979 was $4.27 per ton, an increase of 7% over the 1978 value, and 9% over the 1977 value. Higher values per ton for volcanic cinder and scoria were also reported in 1979; they were 25% more than the 1978 value and 30% more than the 1977 value. The weighted average value for pumice and related volcanic materials sold and used in 1979 was $3.62 per ton, compared with $3.04 per ton in 1978 and $2.98 per ton in 1977. With few exceptions, average values per ton for the principal end uses of pumice, pumicite, volcanic cinder, and scoria in 1979 were higher than the 1978 and 1977 values (tables 3 and 4).

FOREIGN TRADE

Imports of pumice, which had declined 15% in quantity in 1978 from the 1977 total of 253,000 tons, further declined in 1979 to 62,000 tons, or 71% less than that imported in 1978. Receipts from Greece, by far the largest supplier of U.S. imports in 1978, decreased significantly in 1979. Italy (51%) and Greece (49%) supplied all but 47 tons of the total quantity imported in 1979.

Several factors primarily accounted for the unusual decrease in pumice imports from Greece. Bad weather conditions and extensive damage to loading and docking facilities on the island of Yali, near Nisyros, Greece, in October 1978 closed down pumice loading operations for nearly a year. Shipments of pumice (totaling 51,600 tons) to the United States from Yali Island were resumed in October 1979.

The quantity of pumice exported by the United States was estimated to be 2,000 tons in 1979. In 1978, exports of pumice were combined with natural corundum and emery.

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[1] Industry economist, Section of Nonmetallic Minerals.

Table 5.—U.S. imports of pumice for consumption, by class and country

Country	Crude or unmanufactured		Wholly or partly manufactured		Used in the manufacture of concrete masonry products		Manufactured, n.s.p.f. value (thousands)
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	
1977:							
Germany, Federal Republic of	1	(1)	(1)	[r]$1	--	--	$18
Greece	938	[r]$7	--	--	215,453	$783	1
Italy	5,352	197	964	79	30,755	[r]128	[r]79
Other[3]	--	--	--	--	--	--	34
Total	6,291	[r]204	964	[r]80	246,208	[r]911	[r]132
1978:							
Canada	--	--	15	1	30	(1)	--
Colombia	1	(1)	--	--	--	--	--
Germany, Federal Republic of	--	--	(1)	1	--	--	7
Greece	1,028	9	--	--	198,173	746	--
Italy	2,386	102	936	86	13,492	70	28
Norway	3	1	--	--	--	--	--
Other[3]	--	--	--	--	--	--	37
Total	3,418	112	951	88	211,695	816	72

See footnotes at end of table.

Table 5.—U.S. imports of pumice for consumption, by class and country —Continued

Country	Crude or unmanufactured		Wholly or partly manufactured		Used in the manufacture of concrete masonry products		Manufactured, n.s.p.f. value (thousands)
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	
1979:							
France	--	--	2	([1])	--	--	1
Germany, Federal Republic of	--	--	([1])	1	--	--	9
Greece	11	5	--	--	25,288	112	--
Italy	3,557	158	867	82	31,943	162	62
Japan	--	--	--	--	45	1	4
Other[4]	--	--	--	--	--	--	47
Total	3,568	163	869	83	57,276	275	123

[r] Revised.

[1] Less than 1/2 unit.

[2] Austria, Canada, Japan, Mexico, Switzerland, and the United Kingdom.

[3] Austria, Mainland China, Japan, the Republic of Korea, Mexico, the Netherlands, and the United Kingdom.

[4] Austria, Canada, Mainland China, Hong Kong, Mexico, Taiwan, and the United Kingdom.

Source: U.S. Customs.

Table 6.—Pumice and related volcanic materials: World production, by country

(Thousand short tons)

Country[1]	1976	1977	1978[p]	1979[e]
Argentina[2]	68	72	77	80
Austria:Pozzolan	13	10	10	10
Cape Verde Islands: Pozzolan[e]	17	17	NA	NA
Chile: Pozzolan	109	175	201	200
Costa Rica[e]	1	1	2	2
Dominica: Pumice and volcanic ash[e]	120	120	120	120
Egypt[e]	([3])	([3])	([3])	([3])
France: Pozzolan and lapilli	[r]703	774	648	650
Germany, Federal Republic of:				
Pumice (marketable)	[r]2,422	1,928	2,301	2,300
Pozzolan	110	131	192	200
Greece:				
Pumice	441	626	827	900
Pozzolan	1,081	1,385	1,565	1,600
Gundeloupe: Pozzolan	[e]220	209	[e]220	220
Guatemala:				
Pumice	NA	NA	22	22
Volcanic ash	26	29	39	40
Iceland	[4]2	8	9	10
Italy:				
Pumice and pumiceous lapilli[e]	[r]820	820	860	860
Pozzolan[e]	[r]6,200	6,300	6,400	6,500
Martinique: Pumice	[e]90	316	[e]310	310
New Zealand	55	31	44	44
Spain[5]	[r]133	1,027	[e]990	1,000
United States (sold or used by producers):				
Pumice and pumicite	906	1,178	1,208	[6]1,173
Volcanic cinder (including scoria)[7]	3,275	2,832	3,553	[6]3,243
Total[8]	[r]16,800	18,000	19,600	19,500

[e] Estimate. [p] Preliminary. [r] Revised. NA Not available.

[1] Pumice and related volcanic materials are also produced in a number of other countries, including (but not limited to) Iran, Japan, Mexico, Turkey, and the U.S.S.R., but output is not reported quantitatively and available information is inadequate for the formulation of reliable estimates of output levels.

[2] Unspecified volcanic materials produced mainly for use in construction products.

[3] Less than 1/2 unit..

[4] Exports.

[5] Includes Canary Islands.

[6] Reported figure.

[7] Includes American Samoa.

[8] Detail does not add to total because of independent rounding.

Rare-Earth Minerals and Metals

By Christine M. Moore[1]

Domestic production of rare-earth oxide (REO) contained in bastnäsite and monazite increased sharply in 1979, due primarily to the sizeable increase in bastnäsite production. Molycorp, Inc., and W. R. Grace & Co. were the principal processors of rare earths in 1978 and 1979. Petroleum catalysts and metallurgical applications were the major end uses both years.

Legislation and Government Programs.—Shipments of rare earths from the U.S. General Services Administration totaled 2,973 short tons REO in 1978 and 1,226 short tons REO in 1979. Stocks of REO contained in sodium sulfate, an intermediate product in the processing of monazite, totaled 505 tons at yearend 1979. Government stocks of yttrium oxide remained unchanged at 237 pounds.

The Tokyo Round of negotiations was completed in 1979, resulting in new tariff agreements between the developed nations of the world. The agreements, which affected rare-earth tariffs, placed most nations on a most-favored-nation status with generally lower rates to be phased in, or staged, over an 8-year period beginning Jan. 1, 1980. The new rare-earth tariff schedule is shown in table 1.

Table 1.—U.S. import duties

Tariff classification	Article	Most favored nation (MFN)		Non-MFN
		Jan. 1, 1980	Jan. 1, 1987	Jan. 1, 1980
601.12, 601.45	Ore and concentrate	Free	Free	Free.
418.40, 418.42, 418.44	Cerium chloride, oxide, compounds	14% ad valorem	7.2% ad valorem	35% ad valorem.
423.003	Rare-earth oxides except cerium oxide	4.8% ad valorem	3.7% ad valorem	25% ad valorem.
632.38	Rare-earth metals (including scandium and yttrium)	4.8% ad valorem	3.7% ad valorem	25% ad valorem.
632.78	Alloys wholly or almost wholly of rare-earth metals (mischmetal)	47 cents per pound	32 cents per pound	$2 per pound.
632.79	Other alloys wholly or almost wholly of rare-earth metals	46 cents per pound plus 5.6% ad valorem	20 cents per pound plus 2.4% ad valorem	$2 per pound plus 25% ad valorem.
755.35	Ferrocerium and other pyrophoric alloys	46 cents per pound plus 5.6% ad valorem	22 cents per pound plus 2.6% ad valorem	$2 per pound plus 25% ad valorem.

DOMESTIC PRODUCTION

Concentrate.—Domestic production of REO in bastnäsite and monazite in 1979 increased 15% from the 1978 level. Production of REO in bastnäsite and monazite in 1978 was slightly below the 1977 level. Bastnäsite continued to be the major domestic source of rare earths; the remainder, less than 10%, was produced from monazite.

Molycorp, Inc., produced bastnäsite concentrate at its Mountain Pass, Calif., facility. According to the annual report of the Union Oil Co. of California, the parent firm of Molycorp, production of REO contained in bastnäsite concentrate totaled 15,595 short tons REO in 1978 and 18,205 tons REO in 1979.

Titanium Enterprises, jointly owned by American Cyanamid Co. and Union Camp Corp., ceased dredging operations for titanium minerals, including monazite, at its Green Cove Springs, Fla., facility during 1979. The company reprocessed tailings from earlier dredging operations to extract monazite, zircon, and staurolite throughout 1978 and 1979. Output of monazite in 1979 remained at the 1978 level.

Humphreys Mining Co. recovered monazite from heavy-mineral concentrates until the last quarter of 1979 when its orebody near Hilliard, Fla., was depleted.

Compounds and Metals.—Molycorp announced plans to add six solvent-extraction units at its Mountain Pass, Calif., facility. The new units, scheduled to begin production in 1981, would increase the separation capabilities for samarium, cerium, lanthanum, neodymium, and praseodymium. Molycorp also planned modifications at its York, Pa. facility that would increase the company's production capacity for high-purity compounds.

Rhône-Poulenc Inc. of France announced plans to build a rare-earth separation facility in Freeport, Tex. The facility, scheduled for startup in 1981, will process monazite.

W. R. Grace & Co. consolidated its industrial catalyst and rare-earth manufacturing and marketing activities in 1978 under one firm known as Davison Specialty Chemical Co.

During 1978 and 1979, Molycorp and W.R. Grace were the principal producers and processors of rare-earth compounds. Production and shipments of both mixed and purified rare-earth compounds in 1978 increased over the 1977 level, with the largest increase reported for production of purified rare-earth compounds. Production of high-purity rare-earth metals decreased 6% during 1978, and returned to the 1977 level in 1979.

Producers of high-purity oxides and compounds during 1978 and 1979 were Molycorp; W.R. Grace, Chattanooga, Tenn.; Research Chemicals Div. of Nucor Corp., Phoenix, Ariz.; Reactive Metals and Alloys Corp. (REMACOR), West Pittsburg, Pa.; and Transelco Div. of Ferro Corp., Penn Yan, N.Y.

Mischmetal production increased in 1978 and again in 1979. REMACOR and Ronson Metals Corp., Newark, N.J., produced mischmetal both years.

Production of rare-earth silicide by Foote Mineral Co., Exton, Pa.; Molycorp; and REMACOR nearly tripled in 1978, compared with the 1977 level, to meet rising demand in metallurgical applicatons. In addition, American Metallurgical Products Co. announced plans to produce 3 to 5 million pounds per year of rare-earth silicide at a new $1 million plant at Springdale, Pa.

Molycorp and Research Chemicals were the major processors of yttrium oxide. Research Chemicals also produced high-purity rare-earth metals during the year.

CONSUMPTION AND USES

Domestic rare-earth processors consumed an estimated 17,000 tons of REO contained in raw materials in 1978, reflecting an 11% increase from the 15,300 tons consumed in 1977. Bastnäsite consumption increased 7%, and monazite consumption increased 10%. Shipments of rare-earth and yttrium products from primary processing plants to domestic end-use consumers were about 11,000 tons contained REO. Consumption and shipment data for 1979 were not available.

The approximate distribution of rare earths and yttrium by end use in 1978, based on information supplied by primary processors and certain consumers, was as follows; petroleum cracking catalysts, 41%; metallurgical uses (including nodular iron and steel, other alloys, and mischmetal), 35%; ceramics and glass, 19%; and miscellaneous (including electrical, arc carbons, and research), 5%.

Consumption of high-purity rare-earth oxides and chemicals increased during 1979, due to growing use of the rare earths in several recently developed appplications. The use of rare earths as phosphor materials in X-ray equipment and color television tubes as well as lighting equipment continued to grow. Bubble memories, which use small amounts of gadolinium, began to be used on a commercial scale. High-purity lanthanum oxide was used in optical fibers.

Consumption of cerium continued to grow for use in glass and ceramic applications as well as metallurgical applications and, by yearend 1979, the supply of cerium was tight.

Rare earths were used in several forms for metallurgical applications. Consumption of rare earths for this end use has increased dramatically in recent years. Production of mischmetal and rare-earth silicide was increased to meet the demand, and imports of these materials supplemented the domestic supply.

Metallurgical applications of rare earths include additives in iron and steel production, additives for magnesium castings, and alloying agents in high-strength low-alloy steel, and in permanent magnets.

An estimated 165 short tons of samarium oxide were consumed in the production of rare-earth cobalt permanent magnets during 1978.[3] Use of this kind of magnet in earrings and necklace clasps accounted for most of the sharp increase from approximately 55 tons of samarium oxide consumed in 1977. Samarium-cobalt permanent magnets were also used in traveling wave tubes, alternators and generators, line printers, and various missile applications.

STOCKS

Stocks of rare earths in all forms, held by 14 producing, processing, or consuming companies, increased 14% during 1978, and by an additional 25% in 1979.

In 1978 and 1979, bastnäsite concentrate stocks held by the principal producer and four other processors, decreased. Yearend inventories of monazite increased markedly during both years. Stocks of mixed rare-earth compounds nearly doubled over the 2-year period, and stocks of purified rare-earth compounds more than doubled in the same period. Stocks of mischmetal and other alloys decreased more than 10% in 1979 after a sharp increase in 1978. Rare-earth silicide inventories to yearend 1978 decreased 22% from the yearend 1977 level and then more than doubled during 1979.

PRICES

The average declared value of imported monazite increased during 1978 to $209 per short ton and again in 1979 to $242 per short ton. The price per short ton of Australian monazite (minimum 60% REO including ThO_2), as quoted in Metal Bulletin (London), increased from A$223 to A$268 ($206 to $248) per ton at yearend 1978 to A$313 to A$357 ($282 to $322) per ton by yearend 1979. Quoted prices for Malaysian xenotime, an yttrium-rich rare-earth mineral, remained at $2 to $3 per pound, c.i.f.

Prices of unleached, leached, and calcined bastnäsite containing 60%, 70%, and 85% REO increased from $.71, $.76, and $.86 per pound of contained REO, respectively, at yearend 1978 to $.85, $.90, and $1.05 per pound of contained REO at yearend 1979. The price of cerium concentrate quoted by American Metal Market remained at the yearend 1978 level of $1.15 per pound during 1979. The price of lanthanum concentrate increased from 85 cents per pound at yearend 1978 to 90 cents per pound at yearend 1979. Mischmetal prices, as quoted by American Metal Market, increased from $3.95 per pound at yearend 1977 to $4.20 per pound during 1978, where the price level remained during 1979.

Chemical Div. of Rhône-Poulenc Inc., Monmouth Junction, N.J., quoted REO prices per kilogram (2.2046 pounds) f.o.b., New Brunswick, N.J., as follows at yearend 1979:

Product (oxide)	Percent purity	Quantity (kilograms)	Price
Europium	99.99	25	$1,500.00
Gadolinium	99.99	50	102.50
Lanthanum	99.9	1,000	9.90
Neodymium	95	500	5.95
Praseodymium	96	500	32.25
Samarium	96	500	38.75
Terbium	99.9	50	985.00
Yttrium	99.99	50	75.00

Nominal prices for various rare-earth materials were also quoted by Research Chemicals in dollars per kilogram at year-end 1979 as follows:

Element	Oxide[1]	Metal[2]
Cerium	$18	$108
Dysprosium	100	270
Erbium	120	450
Europium	1,650	6,500
Gadolinium	120	430
Holmium	375	1,100
Lanthanum	17	108
Lutetium	4,200	[3]6,600
Neodymium	65	250
Praseodymium	110	290
Samarium	110	280
Terbium	825	2,000
Thulium	2,650	[3]3,500
Ytterbium	180	720
Yttrium	74	320

[1] Minimum 99.9% purity, 1 to 20 kilograms.
[2] Ingot form, 1 to 5 kilograms.
[3] Per 500 grams.

FOREIGN TRADE

Exports of ferrocerium and other pyrophoric alloys containing rare earths totaled 38,056 pounds in 1978. Major destinations were Canada (30%), Mexico (22%), and Venezuela (12%). In 1979, exports more than doubled, totaling 84,100 pounds. The Republic of Korea received 63% of the shipments. In 1978, 545 tons of monazite valued at $87,500 were exported to France. No exports of monazite were reported in 1979.

Imports for consumption of rare earths, shown in Table 3, continued to increase, with a marked increase in the quantity received from France in 1978 and 1979. Monazite imports during 1979 included 3 tons from the Republic of South Africa, the first reported receipt from that country since 1966.

Table 2.—U.S. imports for consumption of monazite

Country	1975		1976		1977		1978		1979	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Australia	--	--	--	--	3,149	$491	5,532	$1,154	6,268	$1,501
Malaysia	2,462	$508	2,103	$431	2,331	409	1,276	255	618	161
South Africa, Republic of	--	--	--	--	--	--	--	--	3	2
Thailand	103	24	--	--	--	--	846	193	42	13
Total	2,565	532	2,103	431	5,480	900	7,654	1,602	6,931	1,677
REO content[e]	1,411	XX	1,157	XX	3,014	XX	4,209	XX	3,812	XX

[e] Estimate. XX Not applicable.

Table 3.—U.S. imports for consumption of rare-earths, by country

	1977		1978		1979	
	Quantity (pounds)	Value (dollars)	Quantity (pounds)	Value (dollars)	Quantity (pounds)	Value (dollars)
Cerium oxide:						
Austria	--	--	--	--	220	$1,002
Belgium	--	--	--	--	2,205	14,150
France	2,425	$9,486	6,920	$40,068	5,840	40,519
Germany, Federal Republic of	--	--	--	--	10	1,624
Japan	--	--	150	309	--	--
Switzerland	14	659	--	--	98	4,769
United Kingdom	2	300	--	--	5,295	53,788
Total	2,441	10,445	7,070	40,377	13,668	115,852
Rare-earth oxide, excluding cerium oxide:						
Belgium	NA	NA	--	--	2,205	49,492
Brazil	NA	NA	--	--	110	880
Canada	NA	NA	37,991	287	--	--
France	NA	NA	193,996	2,095,182	535,230	7,660,675
Germany, Federal Republic of	NA	NA	64,310	887,775	136,729	3,276,152
Japan	NA	NA	--	--	44,028	1,298,004
Malaysia	NA	NA	--	--	35,274	152,232
Norway	NA	NA	2,428	75,909	8,479	282,976
Switzerland	NA	NA	663	102,000	--	--
U.S.S.R.	NA	NA	73,672	3,329,576	85,696	2,417,062
United Kingdom	NA	NA	365	15,235	330	15,996
Total	NA	NA	373,425	6,505,964	848,081	15,153,469
Rare-earth metals (alloys):						
Austria	220,488	639,470	66,339	213,287	--	--
Brazil	149,389	358,846	312,646	805,030	44,092	159,070
France	--	--	110	346	1,212	14,331
Germany, Federal Republic of	55,228	230,726	102,694	392,091	352	2,728
Italy	--	--	200,868	620,160	--	--
Japan	70,245	189,118	92,593	242,746	22,046	63,626
U.S.S.R.	3,303	27,013	--	--	--	--
United Kingdom	--	--	45,294	116,005	77,162	337,407
Total	498,653	1,445,173	820,544	2,389,665	144,864	577,162
Rare-earth metals, including scandium and yttrium:						
France	--	--	3,045	41,061	4,079	52,129
U.S.S.R.	55	1,875	9,470	192,413	4,412	104,592
United Kingdom	36	9,933	114	26,958	483	29,277
Total	91	11,808	12,629	260,432	8,974	185,998
Other rare-earth metals:						
Germany, Federal Republic of	1,147	23,508	70	4,137	1	261
Ferrocerium and other pyrophoric alloys:						
Austria	--	--	613	4,868	414	3,821
Belgium	--	--	220	2,500	--	--
Brazil	1,842	5,574	5,040	16,934	417	750
France	40,304	233,806	73,060	380,803	92,123	518,935
Germany, Federal Republic of	659	2,592	--	--	74	1,663
Hong Kong	179	332	1,681	1,653	--	--
Italy	--	--	7,518	39,954	--	--
Japan	750	3,605	41,047	186,769	29,000	143,810
Switzerland	750	8,382	8	648	4	352
United Kingdom	1,392	8,146	895	7,255	1,186	10,281
Total	45,876	262,437	130,082	641,384	123,218	679,612

NA Not available.

WORLD REVIEW

World production of monazite increased for the fourth consecutive year, due to rapid expansion of Australian production. Bastnäsite production also increased in 1979. Those countries with processing capability for various rare-earth products included Austria, France, the Federal Republic of Germany, Japan, the U.S.S.R., and the United Kingdom.

Australia.—According to the Mineral Sands Producers' Association Ltd., monazite production in short tons was as follows:

State	1977	1978	1979
New South Wales	327	372	1,861
Queensland	683	--	--
Western Australia	8,636	16,147	16,162
Total	9,646	16,519	18,023

Associated Minerals Consolidated Ltd. and Consolidated Rutile Ltd., agreed to jointly mine and process zircon, rutile, monazite, and other heavy minerals located along a common lease boundry on North Stradbroke Island, Queensland. Jennings Industries announced plans to sell its leases on monazite-bearing lands near Eneabba to Consolidated Goldfields of Australia. The company's processing facilities and equipment at Eneabba and Geraldton were to be sold to Associated Minerals Consolidated, a subsidiary of Consolidated Goldfields of Australia.

Western Titanium Ltd., a subsidiary of Associated Minerals Consolidated, announced plans to increase rutile production at its Eneabba heavy minerals separation facility. The company produced monazite concentrates at the plant.

E.I. du Pont de Nemours & Co., Inc., became the major shareholder in Allied Eneabba Pty. Ltd., a major monazite producer, by increasing its equity to 58.5%. The remaining 41.5% equity was held by public shareholders.

Brazil.—A group of 10 banks headed by Chemical Bank of New York loaned Government-owned Mineração Vale do Paranaiba $30 million to investigate a carbonatite complex at Tapira, Minas Gerais. The company's initial plans were to develop processing facilities for phosphate. Associated minerals that may be processed include anatase, columbium, and rare-earth ores.

Canada.—Denison Mines Ltd. ceased production of yttrium concentrates from uranium tailings at its Elliot Lake, Ontario, facilities due to high production costs. The facilities were scheduled to remain on a care-and-maintenance basis.

A summary of rare-earth occurrences in Canada was issued.[3]

China, Mainland.—Inoue Japax Research Inc. concluded an agreement with the Government of China to undertake joint research and development of rare-earth technology, including ore analysis, ore dressing, and product applicaton.

Two rare-earth treatment facilities were reportedly under consideration by the Government of China—one at Baotou to produce 5,500 tons per year of concentrate and a second, at an unannounced location, to produce 1,100 tons per year.

Mitsui Metal Mining Co. and Mitsui & Co. sent teams to China to investigate a possible joint project involving development of rare-earth processing based on the Poyun iron ore deposit.

India.—The Orissa Sand Complex Project, a venture of Indian Rare Earths Ltd., was established to begin work on mineral sands separation facilities near Chatrapur, Orissa. The complex would produce monazite, synthetic rutile, zircon, and sillimanite.

Japan.—Sumitimo Metal Mining began production of samarium-cobalt magnet alloys at Kunitimo, Hokkaido. The company plans to double the capacity of the 44-short-ton-per-year plant by 1980. Production of samarium-cobalt magnets in Japan was 20 short tons in 1976, 45 tons in 1977, and was estimated at 66 tons in 1978.

Kenya.—The Government of Kenya approved the assignment of the right to develop a rare-earth deposit at Mrima Hill to Rhône-Poulenc Inc.

Malaysia.—A Japanese group reportedly began studies of rare-earth resources in Malaysia.

Norway.—Mitsubishi Chemical Industries Ltd. and Megon A/S formed MCI-Megon to process Malaysian xenotime concentrate to high-purity yttrium oxide at a facility in Kjeller, Norway.

Sri Lanka.—In 1978, Ceylon Mineral Sands Corporation reportedly began stockpiling approximately 300 long tons per year of crude monazite that resulted from processing heavy mineral sands for ilmenite, rutile, and zircon.

United Kingdom.—Steetly Chemicals Ltd. began production of various rare-earth oxides, chlorides, and hydrates from imported monazite at Widnes. The facility reportedly has a rated capacity of 1,650 tons per year REO.

Table 4.—Monazite concentrates: World production, by country

(Short tons)

Country[1]	1976	1977	1978[p]	1979[e]
Australia	[r]5,853	9,377	14,864	17,000
Brazil	1,775	2,691	[e]2,700	2,700
India[e]	3,300	3,014	3,607	3,100
Korea, Republic of[e]	10	10	10	10
Malaysia[2]	2,071	2,179	1,392	2,200
Nigeria[e]	20	20	20	--
Sri Lanka	1	[e]5	220	220
Thailand	--	--	845	800
United States	W	W	W	W
Zaire	265	106	85	85
Total	[r]13,295	17,402	23,743	26,115

[e]Estimate. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.

[1]In addition to the countries listed, Indonesia and North Korea may produce monazite, but output, if any, is not reported quantitatively, and available general information is inadequate for formulation of reliable estimates of output levels.

[2]Exports.

TECHNOLOGY

General Motors investigated a new method of fabricating thin curved rare-earth cobalt magnets.[4] The process involves two steps to compact rare-earth cobalt powder to precise final shape, including a means of gently restraining the pressed part to allow it to shrink during sintering to its final density of 96% of its theoretical density. The process would reportedly lower manufacturing costs by eliminating the need for diamond grinding, and reducing material waste and the potential for magnetic breakage. The magnet used in the investigation was made of 75% samarium and 25% mischmetal in a 1:5 rare-earth to cobalt ratio.

A chemical engine using a lanthanum-nickel alloy powder was investigated to recycle heat from low-temperature industrial process fluids and gases.[5] When the powder is heated, the lanthanum-nickel emits hydrogen at sufficient pressure to operate a piston in a cylinder. The new development enables the use of heat of less than 100°C.

The U.S. National Aeronautics and Space Administration elected to study processing of neodymium^{+3}-doped laser glass as one of the 14 programs in its materials-processing programs aboard the space shuttle transport.[6] The anticipated suppression of crystallization by containerless processing could be used to extend the glass-forming region, which presumably would result in the ability to produce a laser glass with an enhanced lasing-line cross section.

An alternative to purification of gadolinium metal by distillation was investigated.[7] The study involved the evaluation of LiF-GdF$_3$ and LiF-BaF$_2$-GdF$_3$ as electrolytes for electrorefining gadolinium. The effects of electrolyte composition and purity, temperature, and current density on the purity of the final product were studied.

A review of fused-salt electrowinning of individual rare-earth metals-yttrium metal, and mischmetal-from their respective chlorides and oxides was published. The article included a review of preparation of alloys of yttrium and rare-earth metals by fused-salt electrolysis and electrorefining of yttrium metal.[8]

The effects of rare earths on the structure and properties of cast irons were reviewed.[9]

Silicon nitride for high-temperature engineering applications was studied by several groups. Two studies reported using yttria as an additive to improve high-temperature properties of silicon nitride.[10] The effects of impurties (Al, Fe, and Ca) in hot-pressing of yttria-doped silicon nitride were discussed.[11] The densification and phase transformation behavior of yttria-doped silicon nitride were studied by comparing its behavior with that of magnesium oxide (MgO)-doped and lithia-doped silicon nitride.[12]

A report on current research concerning rare earths in the U.S.S.R. was published.[13] Included in the report were industrial and military uses of rare earths as well as descriptions of ongoing research for the use of rare earths in laser systems, electronic applications, magnetohydrodynamic power generation, refractory applications, and catalysts.

Researchers at Oak Ridge National Laboratory developed a cyclic process using ceric oxide to generate hydrogen from water or carbon monoxide from carbon dioxide at temperatures within the range of present solar-thermal technology.[14]

The Bureau of Mines began studies to increase rare-earth recovery from bastnäsite as well as to cut energy consumption in the flotation process. A patent application was filed for a rare-earth-metal cobalt magnet containing copper and magnesium developed by the Bureau. The magnet does not contain samarium as an essential component.[15]

Results of research involving the production, characteristics, and use of rare-earth cobalt intermetallic compounds and permanent magnets were summarized at the Third and Fourth International Workshops on Rare-Earth-Cobalt Permanent Magnets.[16]

The 14th Rare Earth Research Conference was held at Fargo, N. Dak., in June 1979. The program reviewed all phases of rare-earth research and development and included sessions on spectrosopy; metallurgy and materials preparation; magnetism; solution, solvation, and analytical chemistry; X-ray and neutron diffraction; and rare-earth technology. Publication of the proceedings was planned.

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Rhenium

By Larry J. Alverson[1]

In 1978, consumption of rhenium increased 71% over that of 1977, reaching a record level of approximately 12,500 pounds. In 1979, consumption fell to about 9,500 pounds as supply remained extremely tight. Demand came primarily from bimetallic catalyst manufacturers as the need for high-octane, low-lead gasoline increased. Imports of ammonium perrhenate reached a record 11,192 pounds in 1978, an increase of 83% over the prior record year of 1977, but declined significantly in 1979. Prices increased in 1978, and reached $2,000 per pound by late 1979.

Table 1.—Salient rhenium statistics

(Pounds of contained rhenium)

	1975	1976	1977	1978	1979
Mine production[e]	2,000	1,500	--	W	W
Consumption[e]	6,000	8,300	7,300	12,500	9,500
Imports (metal)	59	82	148	449	927
Imports (ammonium perrhenate)	[e]966	4,047	6,111	[1]12,042	8,299
Stocks, Dec. 31[e]	21,000	18,300	17,300	W	W

[e] Estimate. W Withheld to avoid disclosing company proprietary data.

[1] Includes 850 pounds of perrhenic acid.

DOMESTIC PRODUCTION

Rhenium was recovered from domestic ores by three companies in 1978 and by one company in 1979. Most of the rhenium recovered in the United States was toll-refined from Canadian molybdenite concentrate (MoS_2) and returned to the owner for sale. Kennecott Corp. resumed recovery of rhenium in late 1978 after being inactive since 1975 and was the sole producer of rhenium from domestic ores in 1979.

CONSUMPTION AND USES

Estimated consumption of rhenium in 1978 increased over 71%, compared with that of 1977, reaching a record level of approximately 12,500 pounds. Consumption dropped to about 9,500 pounds in 1979 as stocks became depleted and supply could not keep pace with demand. The increase in demand over previous years was due to strong demand for bimetallic petroleum reforming catalysts used in producing unleaded and low-lead, high-octane gasoline. The petroleum industry uses several types of catalytic reformers to produce high-octane, low-lead gasoline. Aggregate capacity of semiregenerative bimetallic reformers increased nearly 13% from 1977 to 1979, to a record 58% of total reforming capacity. Capacity of cyclic bimetallic reformers increased over 120% during the same period, and capacity of all other types of reformers increased 55%. In 1972, semiregenerative bimetallic reformers comprised only 28% of total reforming capacity, compared with 45% for comparable monometallic reformers. In 1979 the semiregenerative monometallic reformers' share of capacity was eroded to 9%, as platinum-rhenium catalysts continued to gain in use over platinum catalysts.

Together the three basic types of rhenium-utilizing reformers comprised a record 73% of domestic reforming capacity, or 2,883,700 barrels per stream day, while conventional platinum catalysts accounted for the remainder.[3]

It is estimated that platinum-rhenium catalysts now account for about 85% of bimetallic reforming capacity, or about 62% of total domestic reforming capacity. The trend for platinum-rhenium catalysts to capture more of the market should continue for several years.

The 20 largest oil companies held 84% of total domestic catalytic reforming capacity, while 147 smaller companies held the remaining 16%.[3]

In 1978, the estimated market for reforming catalysts was about 5 million pounds. Approximately 70% of the market was for bimetallic catalysts, which were selling for $4.80 per pound without the precious metal. The cost of bimetallic replacement catalysts was nearly $17 million. In addition, an estimated $5.7 million was spent on monometallic platinum replacement catalysts, $1.9 million on recovering precious metal from catalysts, $8.8 million for replacing metal lost in recovery, and $2.2 million for metal used in new capacity scheduled to come onstream during the year. Thus, nearly $27.5 million was spent in the reforming catalyst market, approximately 70% of which was for bimetallic catalyst to replace the older monometallic type.

Gross weight of existing catalysts in domestic reformers totaled about 15.5 million pounds in 1978, with about 5 million pounds replaced during the year. Bimetallic catalysts generally contained 0.3% rhenium and 0.3% platinum. The newest generation of catalysts contain 0.6% or more rhenium, which helped increase demand for rhenium.

Recovery of metals from reforming catalysts has become a strongly competitive business. Recovery of platinum averages 98% to 99%, and rhenium recovery reportedly averages about 93%. Platinum recovery costs for one company averaged $1.90 per pound. Engelhard Metals & Minerals Corp. and UOP Inc. were leading processors for domestic and foreign operations.[4]

The bimetallic platinum-rhenium catalysts employed in the reformers of the Cities Service Co. at Lake Charles, La., were licensed by two companies to Cities Service. Catalyst for one of the units has been regenerated 10 times and is reportedly functioning well. The ability to be regenerated is one of the attractions of the bimetallic over the monometallic catalysts. Under normal conditions these catalysts can be regenerated almost indefinitely. However, conditions prevailing in 1978-79 were not normal. Refiners were trying to maintain high octane levels in low-lead and lead-free gasolines, which put a greater strain on the catalyst than occurs under more normal conditions. In view of this, 3 years between catalyst regenerations was considered a good performance.

UOP had 12 continuous Platformers in operation with continuous catalyst cycles in which the initial catalyst charge reportedly was performing well. Four units have been operating in excess of 3 years, and an additional six units were scheduled to begin operation in 1979.

Engelhard Minerals and Chemicals Corp. catalysts have been in use for many years and have undergone many regenerations. Over 60 units currently use the E-500 and E-600 series bimetallic catalysts.

Most of the increased rhenium demand came from converting monometallic reformers to bimetallic reformers and increasing the charge capacity of existing bimetallic reformers. The following additions to charge capacity were made (barrels per stream day): Chevron Oil Co., 2,800, to the Bakersfield, Calif., refinery; Murphy Oil Co., 1,500, to the Meraux, La., refinery; Amoco, 1,000, to the Texas City, Tex., refinery; Arco, 3,000, to the Carson, Calif., refinery; Exxon Co., 60,000, to the Baytown, Tex., refinery; and Shell Oil Co., 1,500, to the Wood River, Ill., refinery. Phillips Petroleum Co. converted the 21,000-barrel-per-stream-day reformer at Kansas City, Kans., from monometallic to bimetallic operation, and Pennzoil Corp. converted the 5,000-barrel-per-stream-day refinery at Shreveport, La., from monometallic to bimetallic operation.

Texaco Inc. was building a new 40,000-barrel-per-stream-day reformer at Port Arthur, Tex. The $180 million project was expected to be completed by 1983. The new unit will increase Texaco's production of gasoline by about 2 1/2%, or 475,000 gallons per day, and boost the company's ability to make unleaded gasoline.[5]

Champlin Petroleum Co. was adding a new continuous catalytic reformer at its Wilmington, Calif., refinery; this was part of a $120 million modernization and expansion program to be completed in early 1981. Gulf Oil Co. added a $60 million refiner to its Port Arthur, Tex., refinery which will boost unleaded gasoline capacity by 30,000 barrels per day. Hill Petroleum Co. was expanding catalytic reforming capacity by 15,000 barrels per day at a cost of $20 million at the Krotz Springs, La., refinery. Completion was expected by mid-1980. Vickers Petroleum Corp. was upgrading its Platformer at Ardmore, Okla., to a continuous catalyst regeneration type, which will result in more capability for producing unleaded gasoline.

Based on total reforming capacity, 8 States have entirely bimetallic reforming capacity; 21 States have none. The remaining 21 States have bimetallic reforming capacity ranging from 12% of total capacity (Indiana) to 94% (Mississippi).

Platinum-rhenium catalysts are also used in the production of benzene, toluene, and xylenes by reforming. Reformate accounts for nearly one-half of domestic benzene production; however, the production utilizes only a small proportion of the rhenium used in catalysts.

The United States is the world's leader in catalytic reforming, averaging 3.84 million barrels per calendar day in 1978. Japan was second with 557,000; followed by the United Kingdom, 452,235; Canada, 450,000; France, 441,050; and the Federal Republic of Germany, 439,772. These countries account for the majority of world consumption of bimetallic platinum-rhenium catalysts, a large portion of which was produced in the United States.

An estimated 8% of rhenium consumption was accounted for by use in high-temperature thermocouples, vacuum tube and flashbulb filaments, X-ray tubes and targets, electrical contacts, heating elements, crucibles, semiconductors, electromagnets, metallic coatings, ionization gages, and high-temperature nickel- and cobalt-base alloys.

Rhenium coatings were used on electrical contacts to resist wear and arc erosion. Rhenium reportedly performed better in this application than either tungsten or platinum-ruthenium, which were also used. Rhenium was applied to contacts for various engine magnetos because of its resistance to material transfer. On initial interruption of a current, a thin oxide film is produced that prevents sticking or welding of the contacts or the transfer of metal across the gap. Restoration of the current causes layering of the oxide film at a thickness that does not significantly impair the efficiency of the contact. The resistance of rhenium to salt water corrosion is an important additional advantage in marine engine magnetos.

PRICES

In early 1978, the price for rhenium metal powder was about $375 per pound, and for perrhenic acid, $350 per pound. These prices fell to nearly $300 per pound by late summer; however, by yearend, unofficial prices rose to about $475 per pound for metal powder and $425 per pound for perrhenic acid. In 1979, the price rose dramatically as demand for bimetallic catalysts outpaced available supply. By yearend 1979, the price for rhenium metal powder rose to about $2,000 per pound, depending on grade, quantity, and buyer-seller relationship. The reduction of tetraethyl lead in gasoline to meet air quality standards set by the Environmental Protection Agency exacerbated the rhenium price increases.

FOREIGN TRADE

In 1978, U.S. imports for consumption of ammonium perrhenate reached the record level of 11,192 pounds, valued at nearly $2.2 million. In 1979, 8,299 pounds was imported, valued at $3.3 million. Smaller amounts of metal powder and wrought rhenium were also imported. Chile and the Federal Republic of Germany continued to be the major sources, together supplying over 99% of total imports in 1978, and 94% in 1979.

The import duty on ammonium perrhenate from countries with market economies was 4% ad valorem; the duty on that from countries with central economies was 25% ad valorem. The duty on rhenium metal from countries with market economies was

5% ad valorem for unwrought metal and 9% ad valorem for wrought metal. The duty on wrought and unwrought metal from countries with central economies was 45% and 25% ad valorem, respectively. There is no duty on rhenium contained in molybdenite concentrate.

Table 2.—U.S. imports for consumption of ammonium perrhenate, by country

(Rhenium content)

Country	1975[e]		1976[1]		1977[1]		1978[1]		1979[1]	
	Quantity (pounds)	Value (thousands)	Quantity (pounds)	Value (thousands)	Quantity (pounds)	Value (thousands)	Quantity (pounds)	Value (thousands)	Quantity (pounds)	Value (thousands)
Chile	--	--	1,280	$606	4,187	$1,087	5,855	$889	4,335	$1,380
Germany, Federal Republic of	401	$165	2,767	801	1,924	533	[2]6,187	1,512	3,898	1,854
Poland	--	--	--	--	--	--	--	--	66	25
Sweden	565	277	--	--	--	--	--	--	--	--
Total	966	442	4,047	1,407	6,111	1,620	12,042	2,401	8,299	3,259

[e] Estimate.
[1] Adjusted by Bureau of Mines.
[2] Includes 850 pounds of perrhenic acid.

Table 3.—U.S. imports for consumption of rhenium metal, by country

(Gross weight)

Country	1975		1976		1977		1978		1979	
	Quantity (pounds)	Value	Quantity (pounds)	Value	Quantity (pounds)	Value	Quantity (pounds)	Value	Quantity (pounds)	Value
Belgium-Luxembourg	28	$11,136	17	$8,687	18	$4,120	15	$6,075	--	--
France	--	--	--	--	--	--	--	--	208	$97,926
Germany, Federal Republic of	30	15,760	65	29,060	130	51,734	434	161,920	498	426,735
U.S.S.R	--	--	--	--	--	--	--	--	220	82,504
Other[1]	1	300	--	--	--	--	--	--	1	478
Total	59	27,196	82	37,747	148	55,854	449	167,995	927	607,643

[1] Includes Austria and Switzerland.

WORLD REVIEW

World production of rhenium totaled an estimated 15,700 pounds in 1978 and 16,000 pounds in 1979. Canada, Chile, and the Federal Republic of Germany accounted for the majority of production in both years.

Porphyry copper deposits in Canada, Chile, and the U.S.S.R. were the major sources of rhenium. Known recovery facilities outside the United States were located in Belgium-Luxembourg, Bulgaria, Chile, France, the German Democratic Republic, the Federal Republic of Germany, Poland, Sweden, the United Kingdom, and the U.S.S.R.

Canada.—All of Canada's rhenium production came from the Island Copper Mine of Utah International Inc. In 1978, an estimated 2,200 tons of MoS_2 concentrate, containing approximately 5,000 pounds of rhenium, was shipped to the United States and Western Europe. The contained rhenium was toll-processed into ammonium perrhenate and perrhenic acid and returned to Utah International. Other porphyry copper mines in British Columbia have significant quantities of rhenium in molybdenite, but rhenium has not been recovered.

A prefeasibility study of several aspects of a major copper-molybdenum-gold-silver-rhenium deposit on Gambier Island, British Columbia, was being carried out by 20th Century Energy Corp. The study will include extensive metallurgical testing to determine specifications for mill design, and will include determination of metal recoveries as well as grades of concentrates of copper and molybdenum. A basis will also be determined for estimating rhenium content of the ore.[6] Ore reserves are estimated at 282 million tons to a depth of 300 feet below sea level, having an overall mean average grade of 0.27% copper and 0.014% molybdenite.

Chile.—Production of rhenium in Chile in 1978 was estimated at 4,400 pounds, contained in approximately 7,000 pounds of ammonium perrhenate. The molybdenite-roasting plant of Molibdenos y Metales, S.A. (MOLYMET), which processes concentrate from the Chuquicamata, El Teniente, El Salvador, and Andina mines, is the only Chilean firm that recovers rhenium. These four mines have rhenium concentrations of approximately 230 ppm (parts per million), 440 ppm, 570 ppm, and 350 ppm, respectively, and are a major source of the world's rhenium supply.

The El Teniente mine, south of Santiago, holds the world's largest reserve of rhenium, an estimated 1.5 million pounds (enough to supply current world demand for 100 years). The ore contains an average 1.5% copper and 0.04% molybdenum.

Los Pelambres is a porphyry copper-molybdenum deposit located about 125 miles north of Santiago and 25 miles east of Salamanca at an altitude greater than 10,000 feet above sea level. Reserves are estimated at 472 million short tons of ore grading 0.78% copper and 0.03% molybdenum. Assuming 300 ppm rhenium in MoS_2, rhenium content would total over 140,000 pounds. The property was purchased by Anaconda Co. in late 1979, for an estimated $20 million. Anaconda plans to spend between $6 million and $8 million over the next 3 years on exploratory drilling.

China, Mainland.—One of the world's largest copper deposits will be developed by Fluor Corp. and is to begin operation in 1984. The deposit has proven reserves of 8.8 million tons of copper with recoverable quantities of rhenium. It is located in Tensing County, about 100 miles east of Nanchang in Kiangsi Province in east-central China. Exploration was continuing at the site, and additional reserves seemed likely to be verified.

Hungary.—Exploration drilling in the late 1960's led to the discovery of the Recsk porphyry copper deposit. This deposit, in the Matra Mountain area of northern Hungary, is now being developed for mining. The copper mineralization is in the form of chalcopyrite with associated pyrite. Molybdenum and rhenium are present in the ore in reportedly recoveralbe quantities. By selective mining of the skarn and porphyry ores, the operators plan to maintain an average grade of 1.3% copper for a production of up to 2.5 million tons of ore annually. Eventually, twice this quantity may be mined.[7]

Mexico.—The Caridad copper mine came onstream on June 2, 1979, about 1 year behind schedule. At full capacity, the mine was expected to produce 600,000 tons per year of concentrate, averaging 32% copper. A flotation plant was expected to be onstream in early 1981 to produce 2,000 tons per year of molybdenum sulfide concentrate. It is not known whether recovery of the contained rhenium will be attempted. Proven reserves are 680 million tons of ore, grading an average 0.67% copper and 0.02% molybdenum. Assuming 250 ppm rhenium in MoS_2, rhenium content would total over 100,000 pounds.[8]

Poland.—A new method of recovering rhenium from ore reportedly was developed by the Non Ferrous Metals Institute at Gliwice. The process was put into practice at the Huta Miedzi copper works at Glagow, which now produces several hundred pounds of rhenium per year.

Romania.—Romanian Chemical Enterprises (ROMCHIM) and UOP Inc. reached agreement for the foreign trade company to license 13 process units at several locations in Romania. Included in the agreement are three Platforming process units, each with a 500,000-ton-per-year naphtha feed for production of high-octane gasoline. Similar UOP bimetallic catalysts are used extensively in reforming operations worldwide.

U.S.S.R.—Oil shales in the Tadzhikistan and Uzbekistan regions of central Asia contain concentrations of molybdenum and rhenium. These concentrations may be extracted by acid solutions. The rhenium concentration in the Tadzhikistan region ranges from 0.74 ppm at the Rauat deposit to 12 ppm at the Garauty deposit; in the Uzbekistan region the concentration ranges from 0.2 ppm in the Baysum deposit to 21 ppm in the Urtabulak deposit.[9]

Yugoslavia.—The Bor and Majdanpek porphyry copper mines in mideastern Yugoslavia contain recoverable quantities of molybdenum and rhenium as well as other minor metals such as germanium and gallium. Additional porphyry deposits are found at Dunitri Potok, Valja Stary, and Cerova, northwest of Veliki Krivelj. They are generally low in molybdenum content but have a comparatively high rhenium content.[10] To date no molybdenum or rhenium is believed to have been recovered; however, plans are being made to recover molybdenum and several other minor metals in the next few years.

TECHNOLOGY

The Bureau of Mines published the final report in its series on recovery of molybdenum and rhenium from offgrade molybdenite concentrates. The Bureau determined that current leakage losses that occur in operation of bipolar flow-through electrooxidation cells can be minimized by incorporating cell design factors that increase the current leakage path. This could be accomplished by sealing the edges of the electrodes in the sides of the cell enclosure and adding nonconductive extensions on the top and bottom of each electrode.

Overall molybdenum and rhenium recoveries of 97% were obtained from flotation concentrates containing 16% to 35% molybdenum. Molybdenum-rhenium extraction was unaffected by the presence of chalcopyrite in the molybdenite concentrate; however, molybdenum extraction declined if the copper content, as chalcocite, exceeded 7%. High-purity molybdenum and rhenium compounds can be recovered from the electrolyzed reaction mass by liquid-solid separation, solvent extraction, and crystallization steps.[11]

Research was conducted to find new methods of warm-rolling work-hardened thin wires of high-strength refractory alloys such as molybdenum-rhenium and tungsten-rhenium into metallic tapes. Different methods of heating were tried. One method involved heating the wire with argon preheated to the desired temperature. The heated gas stream was directed into the space between the rolls, heating both the wire and the rolls. Due to the large difference between the masses and the heat-removal capacities of the rolls and the wire, the wire attained the maximum temperature, not in the deformation zone (at the point of contact with the rolls) but some distance away from the entry point. This resulted in some improvement in the form coefficient (width-to-thickness ratio) of the molybdenum-rhenium alloy wire and in the quality of its surface and edges. Similar results were obtained when both the rolls and the wire were indirectly heated by an electrically heated tungsten spiral. It was possible to obtain a molybdenum-rhenium tape with form coefficients of 20 to 25 and higher, retaining all strength and elastic properties with good quality of surface and edges. Also, for the first time, it became possible to cold-roll a difficult material like the tungsten-rhenium alloy (VR27-VP) and obtain a tape with a form coefficient of 10 to 12 from highly cold-hardened wire of 0.08 millimeter diameter, while retaining strength and elasticity.[12]

The need to construct reliable special-purpose electrovacuum devices created demand for new materials for cores of oxide cathodes and for other parts of the cathode unit. Alloys of nickel with magnesium, silicon, calcium, aluminum, tungsten, and other metals had certain deficiencies. All suffered from a high ratio of volatilization, inadequate stability of form, and low strength at elevated temperatures. To meet the complex property requirements, a series of nickel-rhenium alloys with various additions was developed. It was found that rhenium improved the strength properties and the stability of nickel. Also, activating additions of elements of the IV-A group and rare-earth elements improved the emission characteristics of the cathode. The stability of the new alloys increased the rigidity of the cathode and ensured the stability of the emission characteristics of valves with short interelectrode distances. In pulse devices, valve life more than doubled. At 1,000°C the strength of nickel-10% rhenium alloys containing activating additions exceeded the strength of a nickel-vanadium cathode alloy by about 90% and exceeded its rigidity by 1.5 to 2 times. It was shown that in nickel-rhenium alloys an intermediate layer of rhenium compounds did not form, and the service life of the valve increased several times.[13]

The catalytic properties of rhenium catalysts were studied in the process of liquid-phase reduction of nitrobenzenes (NB). It was found that the specific activity of rhenium depends little on the concentration of the active component in the catalyst and was close to that of palladium and much superior to that of nickel. A study of the effect of NB concentration and hydrogen pressure on the activity and stability of a 5% rhenium catalyst (percent metal on charcoal) showed that in the concentration range of 10% to 50% NB, the reaction proceeded almost at a constant rate, with apparent activation energy of about 7,000 calories per mole. Total conversion of NB was obtained at 180° to 200°C. A considerable advantage of rhenium catalysts in NB reduction is their high selectivity. Being superior to palladium and nickel catalysts in productivity, the 5% rhenium catalysts showed a high working capacity over a wide range of contact loads, which is of great importance in its industrial use in columntype contact reactors. A comparison of the relative costs of rhenium-base catalysts with the cost of nickel-, platinum-, and palladium-base hydrogenation catalysts on granulated carbon showed that the 5% rhenium catalyst is competitive with 1% platinized carbon. The 2% rhenium catalyst is a promising substitute for 0.5% platinum or 2% palladium catalysts in the reduction of temperature-stable nitrocompounds.[14]

A patent was applied for in 1978 on a catalytic composition for the reforming of petroleum hydrocarbons. The catalyst consists of 0.1 to 2.0 weight-percent rhenium and 0.1 to 2.0 weight-percent gallium. The catalyst was supported on a solid, porous, refractory, inorganic oxide material. This and similar research was intended to obviate the need for expensive platinum i bimetallic catalysts without sacrificing de sirable qualities that platinum imparts.[15]

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Salt

By Russell J. Foster[1]

The amount of domestically produced salt sold or used by U.S. producers decreased to 42.9 million tons in 1978, but made a strong recovery to 45.8 million tons in 1979. The quantity of all types of salt sold or used increased in 1979 in contrast to the previous year, when only solar salt exhibited a gain. Imports exceeded 5 million tons each year.

Legislation and Government Programs.—The Bureau of Mines has funded a cooperative agreement with the Solution Mining Research Institute to identify the mechanics and causes of sinkholes and to develop methods and design criteria for preventing or predicting sinkhole occurrence at salt solution mines.

The Mine Safety and Health Administration reclassified four Louisiana rock salt mines as "gassy" in 1979 because of detected levels of methane. These operations must now comply with additional safety regulations regarding permissible equipment and blasting procedures.

A report by a select scientific committee on the health effects of sodium as a food additive was presented to the Food and Drug Administration (FDA). The committee recommended a reduction in sodium chloride consumption by the population. If FDA concurs, sodium would be subject to regulations covering processed food additives, which could lead to limits on the amount of salt in foods or requirement of label disclosure.

The U.S. Department of the Interior has selected Virginia Beach, Va., and Alamogordo, N. Mex., as the first two sites for predesign studies of major desalination demonstration plants using state-of-the-art technology.

Table 1.—Salient salt statistics

(Thousand short tons and thousand dollars)

	1975	1976	1977	1978	1979
United States:					
Production[1]	41,710	43,801	42,922	42,878	46,317
Sold or used by producers[1]	41,030	44,191	43,412	42,869	45,793
Value	$368,063	$430,959	$451,579	$499,345	$538,352
Exports	1,832	1,007	1,008	776	[e]793
Value	$9,070	$10,326	$10,881	$9,795	$9,489
Imports for consumption	3,215	4,352	4,529	5,380	5,275
Value	$15,272	$23,476	$26,694	$34,247	$40,860
Consumption, apparent	42,913	47,536	46,933	47,473	[e]50,275
World: Production	178,207	[r]176,305	174,567	180,505	184,958

[e]Estimate. [r]Revised.
[1]Excluding Puerto Rico: Estimated 27,000 short tons per year (1975-79).

DOMESTIC PRODUCTION

The quantity of domestic salt sold or used by producers in 1978 decreased to 42.9 million tons, with only solar salt showing a gain. In 1978, 50 companies operated 90 salt-producing plants in 17 States. Thirteen of the companies sold or used over 1 million tons each, accounting for 85% of the U.S. total.

Domestic producers sold or used 45.8 million tons of salt of their own production in

1979, as all types of salt displayed increases. Fifty companies produced salt at 90 plants in 17 States in 1979. Over 1 million tons of salt was sold or used by 11 of the companies, representing 81% of the national total.

The five leading States in the amount of salt sold or used follow:

State	Percent of total	
	1978	1979
Louisiana	33	31
Texas	21	25
New York	14	14
Ohio	9	9
Michigan	9	7
Total	86	86

The percentage of salt sold or used by domestic producers in 1978 and 1979 by type follows:

	Percent	
	1978	1979
Salt in brine	52	54
Mined rock salt	34	32
Vacuum-pan salt and grainer or open-pan salt	9	9
Solar-evaporated salt	5	5

Cargill, Inc., announced plans to expand evaporated salt capacity by 40% at Breaux Bridge, La., and rock salt capacity by 50% at Lansing, N.Y.[2] The company acquired Leslie Salt Co., the Nation's principal solar salt operation, based at Newark, Calif., for nearly $30 million in 1978.[3]

Great Salt Lake Minerals and Chemicals Corp. completed construction of a new salt plant at Ogden, Utah, in 1979. The facility has tripled the company's processed salt capacity.[4]

International Salt Co. reported capacity increases at Avery Island, La., with the introduction of new loading and hauling units, and at Retsof, N.Y., because of improvements in underground transportation and hoisting.[5]

Carey Salt Co. was purchased by Processed Minerals, Inc., a wholly owned subsidiary of Canadian Pacific Investments, Ltd.[6]

Mild weather at the onset of the 1979-80 winter diminished the possibility of a deicing salt shortage in the Midwest that was expected because of several factors affecting rock salt availability in 1979. An explosion closed the Patterson, La., mine of Cargill, Inc., from early June to the beginning of December. Production at Morton Salt Co.'s Weeks, La., operation was reduced coincident with the conversion of the mine to a strategic petroleum reserve storage site prior to the completion of a replacement salt mine. A strike of 3 months' duration occurred at International Salt Co.'s Cleveland, Ohio, site. In addition rock salt stockpiles were reduced by heavy demand in the previous winter, and transportation was reportedly difficult to obtain.

CONSUMPTION AND USES

Domestic consumption of salt increased to 47.5 million tons in 1978. In the chemical industry production of chlorine and caustic soda increased, but synthetic soda ash output declined because of reduced capacity. Heavy demand for highway deicing salt at the beginning of 1978, coupled with transportation difficulties caused by frozen waterways, created shortages in certain regions.

In 1979 salt consumption in the United States reached an estimated 50.3 million tons, primarily because of greater chlorine and caustic soda output. The decline in salt demand for synthetic soda ash production continued as only one plant remained onstream. Concern over the aforementioned possibility of a deicing salt shortfall prompted many consumers to attempt to secure supplies well in advance of the 1979-80 winter season.

Salt usage by the water-conditioning and oil industries continued to climb significantly in both years.

STOCKS

Total yearend salt stocks as reported by producers amounted to 2.2 million tons in 1978 and 1.5 million tons in 1979. Most was in the form of rock and solar salt.

Table 2.—Salt sold or used by producers in the United States,[1] by method of recovery

(Thousand short tons and thousand dollars)

Recovery method	1978		1979	
	Quantity	Value	Quantity	Value
Evaporated:				
Bulk:				
Open pans or grainers, and vacuum pans	3,463	203,834	3,726	229,662
Solar	2,001	29,348	2,104	25,575
Pressed blocks	381	20,625	391	19,727
Total[2]	5,845	253,808	6,221	274,965
Rock:				
Bulk	14,630	147,753	14,827	148,205
Pressed blocks	58	3,041	64	3,987
Total	14,688	150,794	14,891	152,192
Salt in brine (sold or used as such)	22,336	94,744	24,681	111,195
Grand total[2]	42,869	499,345	45,798	538,352

[1] Excludes Puerto Rico.
[2] Data may not add to totals shown because of independent rounding.

Table 3.—Salt sold or used by producers in the United States, by State

(Thousand short tons and thousand dollars)

State	1978		1979	
	Quantity	Value	Quantity	Value
Kansas[1]	1,661	48,097	1,900	61,184
Louisiana	14,263	110,472	14,207	113,167
Michigan	3,741	83,872	3,080	82,540
New York	5,879	77,236	6,387	77,751
Ohio	3,897	74,572	4,135	79,598
Texas	9,100	49,153	11,283	67,602
Utah	956	13,532	1,204	14,723
West Virginia	1,030	W	1,078	W
Other States[2]	2,342	42,411	2,520	41,787
Total[3]	42,869	499,345	45,798	538,352
Puerto Rico[e]	27	639	27	639

[e] Estimate. W Withheld to avoid disclosing company proprietary data; included with "Other States."
[1] Quantity and value of brine included with "Other States."
[2] Includes Alabama, Arizona, California, Colorado, Hawaii, Kansas (brine only), Nevada, New Mexico, North Dakota, Oklahoma, and items indicated by symbol W.
[3] Data may not add to totals shown because of independent rounding.

Table 4.—Evaporated salt sold or used by producers in the United States, by State

(Thousand short tons and thousand dollars)

State	1978		1979	
	Quantity	Value	Quantity	Value
Kansas	854	40,732	976	51,780
Louisiana	266	18,996	318	22,545
Michigan	1,113	64,012	1,116	64,003
New York	612	37,843	709	44,951
Utah	921	13,355	1,128	14,371
Other States[1]	2,079	78,869	1,973	77,316
Total[2]	5,845	253,808	6,221	274,965
Puerto Rico[e]	27	639	27	639

[e] Estimate.
[1] Includes Arizona, California, Hawaii, New Mexico, North Dakota, Ohio, Oklahoma, and Texas.
[2] Data may not add to totals shown because of independent rounding.

Table 5.—Rock salt sold by producers in the United States

(Thousand short tons and thousand dollars)

Year	Quantity	Value
1975	14,283	107,912
1976	15,668	125,682
1977	14,958	136,437
1978	14,688	150,794
1979	14,891	152,192

Table 6.—Pressed-salt blocks sold by original producers of salt in the United States

(Thousand short tons and thousand dollars)

Year	From evaporated salt		From rock salt		Total	
	Quantity	Value	Quantity	Value	Quantity	Value
1975	436	17,808	84	3,733	520	21,541
1976	412	18,401	76	3,807	[1]487	22,208
1977	388	19,307	65	3,281	453	22,588
1978	381	20,625	58	3,041	439	23,666
1979	391	19,727	64	3,987	455	23,714

[1] Data do not add to total shown because of independent rounding.

Table 7.—Distribution of salt sold or used by producers in the United States, by use

(Thousand short tons)

Consumer or use	1978				1979			
	Evaporated	Rock	Brine	Total[1]	Evaporated	Rock	Brine	Total[1]
Chlorine, caustic soda, and soda ash	425	1,734	21,577	23,735	557	1,819	23,824	26,200
All other chemicals	397	614	148	1,159	446	625	150	1,222
Textile and dyeing	126	57	--	182	134	53	--	188
Meatpackers, tanners, and casing manufacturers	226	314	--	540	259	287	--	546
Dairy	72	5	--	77	78	7	--	85
Canning	150	104	(2)	254	181	99	(2)	280
Baking	W	W	--	111	109	10	--	119
Flour processors (including cereal)	65	26	(2)	91	70	25	(2)	95
Other food processing	644	42	(2)	685	204	56	(2)	261
Feed dealers	767	430	--	1,197	688	506	--	1,194
Feed mixers	343	312	--	654	364	359	--	723
Metals	44	302	(2)	346	70	286	(2)	356
Rubber	W	13	W	96	W	9	W	99
Oil	131	93	226	451	228	103	218	550
Paper and pulp	W	154	W	221	W	134	W	194
Water softener manufacturers and service companies	402	362	(2)	764	464	345	(2)	810
Grocery stores	811	246	(2)	1,057	887	253	(2)	1,140
Highway use	231	8,251	5	8,487	308	8,433	(2)	8,742
U.S. Government	23	63	(2)	86	20	58	(2)	78
Distributors (brokers, wholesalers, etc.)	438	645	--	1,083	588	W	W	1,249
Miscellaneous[3]	648	976	377	[4]1,740	603	1,430	491	[4]1,714
Total[1]	[5]5,941	[5]14,742	[5]22,333	[6]43,016	[5]6,260	[5]14,901	[5]24,684	[6]45,844

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous."

[1] Data may not add to totals shown because of independent rounding.

[2] Less than 5 units; included with "Miscellaneous."

[3] Includes withheld figures and some exports and consumption in overseas areas administered by the United States.

[4] Incomplete totals; withheld totals are included with total for each specific use.

[5] Differs from totals shown in tables 2, 4, and 5 because of changes in inventory.

[6] Differs from totals shown in tables 1, 2, and 3 because of changes in inventory.

Table 8.—Distribution (shipments) of evaporated and rock salt in the United States, by destination

(Thousand short tons)

Destination	1978				1979			
	Evaporated		Rock		Evaporated		Rock	
	Domestic	Imported	Domestic	Imported	Domestic	Imported	Domestic	Imported
Alabama	60	--	353	--	56	--	402	--
Alaska	W	--	(1)	--	W	--	--	--
Arizona	W	--	W	--	63	--	3	--
Arkansas	28	--	66	--	30	--	87	--
California	910	--	1	--	774	--	1	--
Colorado	167	--	35	--	131	--	47	--
Connecticut	23	16	W	(1)	25	W	W	--
Delaware	6	W	W	--	5	W	W	--
District of Columbia	2	1	W	--	W	W	W	--
Florida	64	W	116	--	67	W	115	--
Georgia	62	W	159	(1)	66	W	129	--
Hawaii	W	--	--	--	W	--	--	--
Idaho	66	--	W	--	72	--	W	--
Illinois	391	W	1,104	W	408	W	1,051	W
Indiana	166	W	551	W	174	W	638	W
Iowa	192	--	321	(1)	204	(1)	323	(1)
Kansas	108	--	260	--	101	--	200	--
Kentucky	41	(1)	626	(1)	39	(1)	728	(1)
Louisiana	58	--	366	--	56	(1)	436	--
Maine	8	(1)	W	W	8	(1)	W	W
Maryland	40	W	W	(1)	51	W	W	(1)
Massachusetts	38	W	W	(1)	44	W	W	W
Michigan	203	2	W	W	202	W	W	W
Minnesota	186	--	282	W	194	--	334	W
Mississippi	22	--	103	--	25	(1)	100	--
Missouri	109	--	500	--	109	W	507	--
Montana	55	--	W	--	56	--	2	--
Nebraska	117	--	129	--	127	--	118	--
Nevada	90	--	W	--	W	--	W	--
New Hampshire	5	(1)	W	W	5	W	W	W
New Jersey	186	132	W	W	213	W	W	W
New Mexico	58	--	29	W	62	--	23	--
New York	313	56	1,630	W	330	31	1,680	W
North Carolina	106	W	154	--	122	W	165	(1)
North Dakota	W	--	3	--	W	--	1	--
Ohio	366	W	1,627	W	367	10	1,718	W
Oklahoma	54	--	76	--	54	--	90	--
Oregon	52	W	--	--	58	W	(1)	--
Pennsylvania	194	78	1,324	W	204	W	1,140	W
Rhode Island	7	W	W	--	8	W	W	W
South Carolina	44	W	14	--	40	W	16	--
South Dakota	44	--	33	--	47	--	35	--
Tennessee	92	--	624	(1)	95	--	595	W
Texas	222	--	272	--	235	--	265	--
Utah	276	--	W	--	301	--	W	--
Vermont	5	(1)	W	--	5	(1)	W	W
Virginia	86	W	242	W	117	W	W	(1)
Washington	75	534	(1)	--	153	511	(1)	--
West Virginia	19	W	301	(1)	23	W	365	(1)
Wisconsin	202	W	485	W	207	W	481	W
Wyoming	36	--	W	--	30	--	W	--
Other[2]	288	792	2,956	1,996	498	1,018	3,107	2,126
Total[3]	[4]5,941	[5]1,608	[4]14,742	[5]1,996	[4]6,260	[5]1,569	[4]14,901	[5]2,126

W Withheld to avoid disclosing company proprietary data; included with "Other."

[1] Less than 1/2 unit.

[2] Includes shipments to overseas areas administered by the United States, Puerto Rico, exports, some shipments to unspecified destinations, and shipments to States indicated by symbol W.

[3] Data may not add to totals shown because of independent rounding.

[4] Differs from totals in tables 2, 4, and 5 because of changes in inventory.

[5] Differs from totals in tables 1, 11, 12, and 13 because of incomplete data on the distribution of imported salt.

PRICES

The average values of different classes of salt, f.o.b. works, as reported by producers follow:

	Per ton	
	1978	1979
Evaporated:		
Open pans or grainers, and vacuum pans	$58.86	$61.64
Solar	14.67	12.16
Pressed blocks, all sources	58.91	52.12
Rock salt, bulk	10.10	10.00
Salt in brine	4.24	4.51

The following salt prices were quoted at yearend 1979 in Chemical Marketing Reporter:[7]

Salt, evaporated, common, 80-pound bags, carlots or truckloads, North, works, 80 pounds	$2.46
Salt, chemical-grade, same basis, 80 pounds	2.67
Salt, rock, medium coarse, same basis, 100 pounds	1.55
Salt, rock, extra coarse, same basis, 100 pounds	1.63

FOREIGN TRADE

Salt exports from the United States declined to 776,000 tons in 1978, but reached an estimated 793,000 tons in 1979. The principal destination of exported salt was Canada.

U.S. imports of salt attained a record level of 5.4 million tons in 1978 that was nearly matched in 1979. Canada, Mexico, and the Bahamas were the main foreign sources of salt.

Table 9.—Salt shipped to the Commonwealth of Puerto Rico and overseas areas administered by the United States

Area	1978		1979	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Puerto Rico	19,597	$3,377	20,944	$3,908
Virgin Islands	27	32	293	16

Table 10.—U.S. exports of salt, by country

(Thousand short tons and thousand dollars)

Destination	1978		1979	
	Quantity	Value	Quantity	Value
Angola	(1)	18	1	78
Bahamas	1	120	1	121
Bermuda	--	--	1	3
Canada	750	6,776	[e]765	7,218
Costa Rica	1	148	1	53
Denmark	5	28	(1)	33
Egypt	1	84	--	--
Germany, Federal Republic of	1	38	(1)	6
Hong Kong	1	18	1	53
Mexico	6	298	[e]12	287
Netherlands Antilles	(1)	28	1	60
Saudi Arabia	6	1,377	3	835
South Africa, Republic of	1	10	(1)	6
Sweden	(1)	20	1	21
Trinidad and Tobago	(1)	26	2	119
United Arab Emirates	(1)	27	1	72
United Kingdom	(1)	111	1	78
Venezuela	(1)	21	1	7
Other	4	646	3	440
Total[2]	776	9,795	[e]793	9,480

[e] Estimate.
[1] Less than 1/2 unit.
[2] Data may not add to totals shown because of independent rounding.

Table 11.—U.S. imports for consumption of salt, by country

(Thousand short tons and thousand dollars)

Country	1978		1979	
	Quantity	Value	Quantity	Value
Bahamas	699	3,219	528	3,985
Brazil	--	--	197	1,625
Canada	[1]2,005	[1]13,141	[2]2,057	[2]15,580
Chile	[3]203	[3]1,398	244	1,699
Colombia	--	--	41	480
Italy	36	346	42	1,205
Mexico	1,600	10,180	1,649	11,282
Netherlands	[4](5)	[4]1	57	960
Netherlands Antilles	251	2,076	175	1,597
Spain	488	2,903	252	1,745
Tunisia	89	552	33	250
United Kingdom	11	67	[6](5)	[6]5
Other	[7](5)	[7]364	[8](5)	[8]447
Total[9]	5,380	34,247	5,275	40,860

[1] Includes salt brine through St. Albans customs district, 24 short tons ($259), and through Buffalo customs district, 2 short tons ($330).

[2] Includes salt brine through Detroit customs district, 239 short tons ($5,370).

[3] Includes salt brine through Philadelphia customs district, 1 short ton ($280).

[4] Includes salt brine through San Juan customs district, 53 short tons ($1,104).

[5] Less than 1/2 unit.

[6] Includes salt brine through Washington customs district, less than 1 short ton ($344).

[7] Includes salt brine from Denmark through Chicago customs district, less than 1 short ton ($1,355), and through Cleveland customs district, 8 short tons ($69,902).

[8] Includes salt brine from Denmark through Cleveland customs district, 6 short tons ($43,410); from Finland through New York customs district, less than 1 short ton ($949); from Sweden through New York customs district, less than 1 short ton ($637).

[9] Data may not add to totals shown because of independent rounding.

Table 12.—U.S. imports for consumption of salt, by class

(Thousand short tons and thousand dollars)

Year	In bags, sacks, barrels, or other packages (dutiable)		Bulk (dutiable)	
	Quantity	Value	Quantity	Value
1977	23	883	[1]4,506	[1]25,811
1978	1	1,209	[2]5,379	[2]33,037
1979	1	1,760	[3]5,275	[3]39,099

[1] Includes salt brine from the Bahamas through San Juan customs district, 35,870 short tons ($182,221); from the United Kingdom through Baltimore customs district, 1 short ton ($963); from Denmark through Cleveland customs district, 3 short tons ($3,695).

[2] Includes salt brine from Canada through St. Albans customs district, 24 short tons ($259), and through Buffalo customs district, 2 short tons ($330); from Chile through Philadelphia customs district, 1 short ton ($280); from the Netherlands through San Juan customs district, 53 short tons ($1,104); from Denmark through Chicago customs district, less than 1 short ton ($1,355), and through Cleveland customs district, 8 short tons ($69,902).

[3] Includes salt brine from Canada through Detroit customs district, 239 short tons ($5,370); from the United Kingdom through Washington customs district, less than 1 short ton ($344); from Denmark through Cleveland customs district, 6 short tons ($43,410); from Finland through New York customs district, less than 1 short ton ($949); from Sweden through New York customs district, less than 1 short ton ($637).

Table 13.—U.S. imports for consumption of salt, by customs district

(Thousand short tons and thousand dollars)

Customs district	1978		1979	
	Quantity	Value	Quantity	Value
Anchorage, Alaska	1	202	1	350
Baltimore, Md	540	3,279	498	4,550
Boston, Mass	133	992	34	270
Buffalo, N.Y	105	708	23	258
Chicago, Ill	376	2,184	519	3,629
Cleveland, Ohio	100	659	16	157
Detroit, Mich	851	4,964	697	5,300
Duluth, Minn	125	1,093	182	1,625
Los Angeles, Calif	237	1,406	150	688
Milwaukee, Wis	349	1,919	520	3,162
New Orleans, La	16	110	132	1,122
New York, N.Y	404	2,731	253	2,449
Norfolk, Va	88	671	109	1,051
Ogdensburg, N.Y	23	175	18	189
Philadelphia, Pa	18	106	36	290
Portland, Maine	399	2,867	485	4,182
Portland, Oreg	403	2,425	436	2,309
Providence, R.I	85	440	109	922
St. Albans, Vt	38	927	25	390
San Juan, P.R	90	1,285	41	341
Savannah, Ga	450	1,572	318	2,197
Seattle, Wash	469	2,983	500	3,416
Tampa, Fla	22	90	16	136
Wilmington, N.C	58	395	158	1,755
Other	(1)	64	1	39
Total[2]	5,380	34,247	5,275	40,980

[1] Less than 1/2 unit.
[2] Data may not add to totals shown because of independent rounding.

Table 14.—U.S. imports for consumption of salt, by use as reported by salt producers

(Thousand short tons)

Use	1978	1979
Government (highway use)	2,203	2,396
Chemical industry	776	762
Water-conditioning service companies	126	148
Other	499	388
Total[1] [2]	3,604	3,695

[1] Disagreement with totals in tables 1, 11, 12, and 13 is because of incomplete data on the uses of imported salt.
[2] Data may not add to totals shown because of independent rounding.

WORLD REVIEW

World salt production reached nearly 181 million tons in 1978. Thirteen nations, the United States, Mainland China, the U.S.S.R., the Federal Republic of Germany, the United Kingdom, France, Canada, Mexico, Italy, Romania, Australia, Poland, and India, accounted for 82% of the world's salt output.

In 1979 salt production was estimated at 185 million tons worldwide. Production from the top 13 countries amounted to about 83% of the total.

Distribution of the production by continent follows:

	Million tons	
	1978	1979
Europe	72.4	78.8
North America	58.7	61.6
Asia	35.0	35.3
South America	6.0	6.1
Oceania	5.2	5.1
Africa	3.1	3.1

Abu Dhabi.—Abu Dhabi National Oil Co. contracted for a seawater-evaporation salt plant and a chloralkali facility, due onstream by yearend 1980.[8]

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Australia.—Storm damage to shiploading and jetty facilities in March 1979 forced Dampier Salt Ltd. to suspend salt production at Lake MacLeod in Western Australia. The company hoped to cover the shortfall by increasing output at its Dampier location, while the Lake MacLeod operation undergoes reconstruction over an estimated 18-month period. Dampier Salt acquired the Lake MacLeod site from Texada Mines Pty. Ltd. in a 1978 merger.[9]

Austria.—A new evaporated salt plant was being constructed at Steinkogel by the national salt producer. The plant will have a capacity of 440,000 tons annually.

Bahamas.—Most of Diamond Crystal Salt Co.'s 1979 solar salt production at Long Island was lost to heavy rains from a hurricane in September.[10]

Canada.—The Government of Quebec has approved the commercial development of salt deposits at Grosse-Ile in the Magdalen Islands in the Gulf of St. Lawrence. Salt from the projected 1.3-million-ton-per-year mine will be used principally for highway deicing. The feasibility of locating a synthetic soda ash plant in the Gaspe region of Quebec is being studied as another possible end use for the salt. Salt shipments from the Magdalen Islands could begin in 1983.[11]

Domtar, Inc., will increase the capacity of its rock salt mine at Goderich, Ontario, by 55% to 3.8 million tons annually over a 2-1/2-year period.[12]

Iraq.—The State Organization for Minerals awarded a contract for the construction of a 660,000-ton-per-year solar salt facility at Fao by 1981. Most of the output will be for industrial consumption, but 82,000 tons per year is slated for food use.[13]

Libya.—The General National Organization for Industrialization announced plans for a chemical complex at Ras Lanuf, connected by pipeline with the salt brine deposits at Marada.[14]

Pakistan.—Pakistan Mineral Development Corp. began production of 220 tons of salt per day at Jatuna in 1978.[15]

Poland.—A new salt mine under construction at Moszczenica is scheduled to come onstream in 1984 with initial capacity of 660,000 tons per year. Production from the mine will largely replace that from the 700-year-old Wieliczka and Bochnia mines, which will continue to produce some high purity salt for food and medicinal uses.[16]

Occidental Petroleum Corp. and the Polish Government were studying the feasibility of establishing a joint venture to develop more of Poland's salt deposits for chemical production.[17]

Thailand.—A proposed synthetic soda ash plant at Sattahip based on Thai salt and limestone resources was reportedly going ahead. Production of soda ash for local industry and export to other member countries of the Association of Southeast Asian Nations is scheduled to begin in 1985 with 9,900 tons and reach a maximum of 550,000 tons in 1997.[18]

U.S.S.R.—Construction continued on a new 2.2-million-ton-per-year salt mine at Artemovsk and on a 1.1-million-ton-per-year mine at Zima. Other salt production facilities were under construction at Verkhnekamsk, Nizhniy Braskunchak, Mozyr, and Sterlitomak. Development of a new mine at Gusev is planned.[19]

Venezuela.—Empresa Nacional de Salinas, the national salt company, announced a combined venture to build a large solar salt works with annual production of 2.8 million tons in the State of Zulia by 1982.[20]

Table 15.—Salt: World production, by country

(Thousand short tons)

Country[1]	1976	1977	1978^{p}	1979^{e}
North America:				
Bahamas	1,491	1,841	^{e}1,800	1,500
Canada	6,607	6,657	7,112	^{2}7,355
Costa Rica	22	30	38	40
Dominican Republic	^{r}43	75	40	40
El Salvador^{e}	25	^{r}30	30	30
Guatemala	12	12	12	12
Honduras	35	$^{r\ e}$35	^{e}35	35
Leeward and Windward Islands^{e}	55	55	55	55
Mexico	5,061	5,401	6,212	6,200
Netherlands Antilles^{e}	530	440	440	440
Nicaragua	^{r}16	$^{r\ e}$18	^{e}20	20
Panama	14	23	17	17
United States, including Puerto Rico:				
Rock salt	15,668	14,958	14,688	^{2}14,882
Other salt:				
United States	28,523	28,454	28,181	^{2}30,911
Puerto Rico^{e}	27	27	27	27

See footnotes at end of table.

Table 15.—Salt: World production, by country —Continued

(Thousand short tons)

Country[1]	1976	1977	1978^{p}	1979^{e}
South America:				
Argentina:				
Rock salt	2	2	1	1
Other salt	727	1,263	1,058	1,100
Brazil	2,726	2,734	3,006	3,100
Chile	472	467	434	430
Colombia:				
Rock salt	^{r}205	190	196	190
Other salt	^{r}1,020	817	632	630
Peru	335	342	540	500
Venezuela	^{e}330	266	174	170
Europe:				
Albania^{e}	55	55	55	70
Austria:				
Rock salt	1	1	1	1
Evaporated salt	^{r}366	356	354	350
Salt in brine	^{r}270	161	172	180
Bulgaria	83	96	^{e}100	100
Czechoslovakia	^{r}269	280	284	290
Denmark	385	346	358	360
France:				
Rock salt	^{r}309	316	505	640
Brine salt	^{r}1,176	1,120	1,215	1,200
Marine salt	1,577	614	953	990
Salt in solution	^{r}3,638	3,847	4,520	4,600
German Democratic Republic:				
Rock salt	2,765	2,855	2,963	3,000
Marine salt	57	58	^{e}58	58
Germany, Federal Republic of:				
Marketable:				
Rock salt	^{r}7,027	7,800	7,546	7,500
Marine salt and other salt	5,448	5,723	6,407	6,500
Greece	^{r}154	209	147	^{3}154
Italy:				
Rock salt and brine salt	3,759	3,969	4,102	4,300
Marine salt	664	1,576	1,334	1,300
Malta	(^{3})	1	^{e}1	1
Netherlands	3,336	3,429	3,240	3,200
Poland:				
Rock salt	1,821	1,722	1,582	1,700
Other salt	2,388	3,081	3,263	3,300
Portugal:				
Rock salt	^{r}338	387	359	350
Marine salt	^{r}180	164	^{e}155	155
Romania:				
Rock salt	4,641	5,000	1,827	1,900
Other salt			3,397	3,400
Spain:				
Rock salt	2,204	1,359	1,400	1,400
Marine salt and other evaporated salt[4]	1,277	1,324	^{e}1,350	1,500
Switzerland	343	[illegible]	481	430
U.S.S.R.^{e}	^{r}15,650	^{r}15,760	15,980	16,200
United Kingdom:				
Rock salt	674	998	1,445	1,500
Brine salt	2,114	2,062	1,940	2,000
Other salt	6,037	5,981	4,678	4,600
Yugoslavia:				
Rock salt	101	94	98	^{3}386
Marine salt	14	23	37	
Salt from brine	204	207	193	
Africa:				
Algeria	150	162	189	180
Angola^{e}	^{r}55	^{r}55	55	55
Benin	(^{3})	(^{3})	^{e}(^{3})	(^{3})
Egypt	530	658	832	840
Ethiopia:[5]				
Rock salt^{e}	11	6	11	11
Marine salt	97	$^{r\,e}$85	^{e}55	55
Ghana^{e}	^{r}100	55	55	55
Kenya:				
Crude	55	44	22	22
Refined	16	14	^{e}13	13
Libya^{e}	11	11	17	11
Madagascar	30	29	33	33
Mali	8	$^{r\,e}$5	^{e}5	5
Mauritania^{e}	1	1	1	1
Mauritius	6	7	7	7
Morocco	24	14	19	20
Mozambique^{e}	31	31	31	31
Niger^{e}	1	1	1	1
Senegal	156	154	154	154

See footnotes at end of table.

Table 15.—Salt: World production, by country —Continued

(Thousand short tons)

Country[1]	1976	1977	1978[p]	1979[e]
Africa: —Continued				
Sierra Leone[e]	200	200	200	200
Somali Republic[e]	2	2	2	2
South Africa, Republic of	247	267	540	[2]594
South-West Africa, Territory of (marine salt)[e]	240	[r]250	250	250
Sudan	77	101	79	100
Tanzania	[r]51	31	22	25
Togo	[e](3)	--	1	1
Tunisia	[r]529	446	469	470
Uganda[e]	[r]1	[r]1	1	1
Asia:				
Afghanistan	77	86	89	22
Bangladesh[5]	[r]606	381	866	800
Burma	[r]139	254	336	330
China:				
Mainland	[r] [e]22,000	[r] [e]19,000	21,536	22,000
Taiwan	546	547	375	[2]404
Cyprus	[r]4	--	--	--
India	[r]4,892	4,144	4,828	5,000
Indonesia	234	621	[e]700	700
Iran[6]	772	772	[e]772	400
Iraq[e]	[r]71	[r]90	90	90
Israel	[r]95	[e]110	134	140
Japan[7]	1,125	1,164	1,183	1,200
Jordan	[r]22	33	33	33
Kampuchea, Republic[e]	33	33	13	6
Korea, Democratic Republic[e]	600	600	600	600
Korea, Republic of	[r]595	606	617	615
Kuwait	17	18	21	20
Laos[e]	11	11	17	20
Lebanon[e]	40	40	13	13
Mongolia[e]	12	[r]17	17	17
Pakistan:				
Rock salt[5]	[r]413	424	455	[2]537
Other salt	[r]159	126	250	[2]211
Philippines	[r]225	220	58	58
Sri Lanka	155	57	165	170
Syrian Arab Republic	60	116	121	130
Thailand:				
Rock salt	6	14	13	[2]12
Other salt[e]	[r]180	[r]180	180	180
Turkey	638	857	1,024	1,000
Vietnam[e]	390	[r]415	415	400
Yemen Arab Republic	110	80	30	100
Yemen, People's Democratic Republic of[e]	83	83	83	83
Oceania:				
Australia (marine salt and brine salt)	[r]6,051	[r]5,197	5,142	5,000
New Zealand	47	58	72	80
Total	[r]176,395	174,567	180,505	184,958

[e]Estimate. [p]Preliminary. [r]Revised.

[1] Salt is produced in many other countries, but quantities are relatively insignificant and reliable production data are not available.

[2] Reported figure.

[3] Less than 1/2 unit.

[4] Includes an average annual production in the Canary Islands of about 30,000 short tons of marine salt.

[5] Year ending June 30 of that stated.

[6] Year beginning March 21 of that stated.

[7] Includes Ryukyu Islands.

TECHNOLOGY

The Vth International Symposium on Salt was held from May 29 through June 1, 1978, at Hamburg, Federal Republic of Germany. The event was attended by representatives from the salt industry, research organizations, and government worldwide, and papers on a variety of topics were presented.

Fluidized-bed combustion of coal in the presence of salt introduces structural rearrangement in the limestone bed material that can lead to an optimum pore distribution and thus enhance its sulfur-removal capacity. This effectively reduces limestone requirements and the amount of solid waste produced.[21]

A major cause for deterioration of highway concrete is the corrosion of steel reinforcement bars by saline water in regions where deicing salt is applied and in seacoast areas. During road construction specialty chemicals such as calcium nitrate can be used to inhibit corrosion, and sealants including wax pellets which are melted by heating the set concrete can be introduced to fill porous areas.[22]

A solar heating system that stores incoming solar energy in ceiling tiles that contain a chemical heat sink consisting primarily of sodium sulfate and water has been developed. The absorption and release of heat is based on a crystalline phase change between two forms of sodium sulfate. However, 8% sodium chloride by weight is also required to achieve the desired melting point for a comfortable room temperature.[23]

The largest salt-gradient solar pond in the United States was built in 1978 at Miamisburg, Ohio, to provide heating for a swimming pool and recreation building. Water in the pond is warmed by the sun, and heat loss due to convection is prevented by higher concentrations of sodium chloride in the deeper parts of the pond.[24]

The search for a sodium nitrite substitute in bacon has led a major food processor to test market a nitrite-free bacon that uses a traditional salt and sugar cure.[25]

Imperial Chemical Industries Ltd. introduced two series of dyes that offer a single-stage continuous process for polyester/-cellulose fabrics and eliminate the need for salt and some other compounds.[26]

Scientific debate continued over the uncertainties involved with geologic containment of glassed-in nuclear wastes in rock salt. Of particular concern is the effect of heat generated by the decay of nuclear waste on the containment medium and surrounding formations.[27]

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Sand and Gravel

By Valentin V. Tepordei[1]

A total of 996 million tons of sand and gravel was reported produced in the United States in 1978 with a value of $2.30 billion. This tonnage is the highest ever reported, 1% above the previous record production of 1973, and 7% above that of 1977. In 1979, production decreased to 979 million tons, 2% below the 1978 record. Value of 1979 production was a record $2.43 billion. Of these totals, 97% was construction sand and gravel and 3% was industrial sand and gravel for both years.

Production of construction sand and gravel increased 7% in 1978 but, then, decreased by 2% in 1979. Production of industrial sand and gravel increased 5% in 1978 and again increased another 2% in 1979. Exports of sand and gravel in 1978 increased

Table 1.—Salient sand and gravel statistics in the United States[1]

(Thousand short tons and thousand dollars)

	1975	1976	1977	1978	1979
Sold or used:					
Construction:					
Processed:					
Sand:					
Quantity	265,404	418,495	439,400	489,800	455,000
Value	448,583	654,389	848,200	989,200	974,100
Gravel:					
Quantity	353,652	436,747	458,400	473,500	490,500
Value	634,931	949,405	968,700	1,064,000	1,170,000
Unprocessed:					
Sand and gravel:					
Quantity	143,097	(2)	(2)	(2)	(2)
Value	106,827	(2)	(2)	(2)	(2)
Total construction:[3]					
Quantity	762,153	855,242	897,900	963,300	945,500
Value	1,190,341	1,603,974	1,817,000	2,053,000	2,144,000
Industrial:					
Sand:					
Quantity	26,723	29,669	29,610	31,810	32,120
Value	146,982	169,127	201,900	234,200	275,200
Gravel:					
Quantity	560	245	1,745	1,041	1,391
Value	2,996	1,109	8,704	5,554	8,574
Total industrial:[3]					
Quantity	27,283	29,914	31,360	32,850	33,510
Value	149,978	170,236	210,600	248,800	283,800
Grand total:[3]					
Quantity	789,436	885,156	929,200	996,200	979,000
Value	1,340,319	1,774,030	2,028,000	2,302,000	2,427,000
Exports:					
Quantity	3,219	3,692	3,680	4,260	2,076
Value	15,047	19,516	21,515	29,270	32,440
Imports:					
Quantity	374	353	386	625	423
Value	777	909	1,278	2,084	1,179

[1] Puerto Rico excluded from all sand and gravel statistics.
[2] Processed and unprocessed are no longer separated.
[3] Data may not add to totals shown because of independent rounding.

15% to 4.2 million tons, but decreased to 2.1 million tons in 1979. Imports of sand and gravel increased 62% in 1978 to 625,000 tons, but decreased in 1979 to 423,000 tons.

As appropriate throughout the remainder of this report, where different values exist for 1978 and 1979, the 1978 values are shown first, with the 1979 values immediately following in parentheses.

Legislation and Government Programs.—In August 1977, the Federal Surface Mining Control and Reclamation Act became Public Law 95-87. Through section 709 of the act, Congress directed the Council on Environmental Quality[*] (CEQ) to sponsor a study regarding the applicability of this law to the surface mining of noncoal minerals. In April 1978, the National Academy of Sciences, under a contract with CEQ formed the Committee on Surface Mining and Reclamation (COSMAR) whose task was to complete the study requested by Congress. In November 1979, COSMAR's final report on "Surface Mining of Non-Coal Minerals" was published. Recognizing its importance, sand and gravel was studied as a separate commodity with the "Working Paper on Sand and Gravel Mining" being published under separate cover as an appendix to the Committee's report. The COSMAR study concluded that the provisions of the Surface Coal Mining Law had only restricted application in the mining of noncoal minerals and suggested that the sand and gravel industry may be regulated on a local government level and not by the Federal Government. The Council on Environmental Quality, which had been assigned responsibility for developing legislation for the mining of noncoal minerals, then scheduled public hearings on the COSMAR report.

In March 1978, the Federal Mine Safey and Health Act of 1977 became effective and was being enforced by the Mine Safety and Health Administration (MSHA) of the U.S. Department of Labor. As a result of the numerous complaints from industry representatives regarding the provisions of the act, its applicability to sand and gravel operations as well as the cost of compliance with its provisions, bill H.R. 1603 was introduced in Congress on January 29, 1979. This bill was designed to amend the Federal Mine Safety and Health Act by stipulating that its provisions shall not apply to sand and gravel operations. As of December 31, 1979, the bill was still pending in the House Committee on Education and Labor.

DOMESTIC PRODUCTION

In 1978 and 1979, the Pacific region led the Nation in the production of construction sand and gravel with 224 (221) million tons or 23% of the U.S. total. Next was the East North Central region with 19% (20%) followed, in 1978, by the West North Central region with 11% of the total and, in 1979, by the Mountain region with 11% of the total. In industrial sand and gravel, the East North Central region led the Nation with 14 (14.2) million tons or 43% (42%) of the national total followed by the South Atlantic region with 14% (16%) and the West South Central region with 11% (13%).

If the four major geographic regions are compared (table 2), the West led the Nation in the production of construction sand and gravel with 34% of the total. North Central was the next with 30% (31%) and the South was third with 24% of the national total. In industrial sand and gravel, the North Central region produced 48% of the national total followed by the South with 30% and North East, a distant third, with 12%.

The five leading States in the production of construction sand and gravel, in order of volume, were California, Alaska, Texas, Ohio (Michigan), and Michigan (Ohio) with 34% of the national total. In industrial sand and gravel, four States produced 49% (47%) of the national total with Illinois (Michigan) first, followed by Michigan (Illinois), New Jersey, and California.

For the combined production of construction and industrial sand and gravel, the five leading States in order of volume were California, Alaska (Texas), Alaska (Texas), Michigan, and Ohio with 34% of the U.S. total.

The top 10 producers of construction sand and gravel in 1978 were, in order of tonnage, Lone Star Industries, Inc.; Conrock Co., Inc.; Gifford-Hill & Co., Inc.; American Aggregates Corp.; Dravo Corp.; Martin-Marietta Aggregates; Kaiser Sand and Gravel Corp.; Owl Rock Products Co.; E. R. Jahna Industries, Inc.; and United Metro Inc.

In 1979, the top 10 producers of construction sand and gravel were, in order, Lone

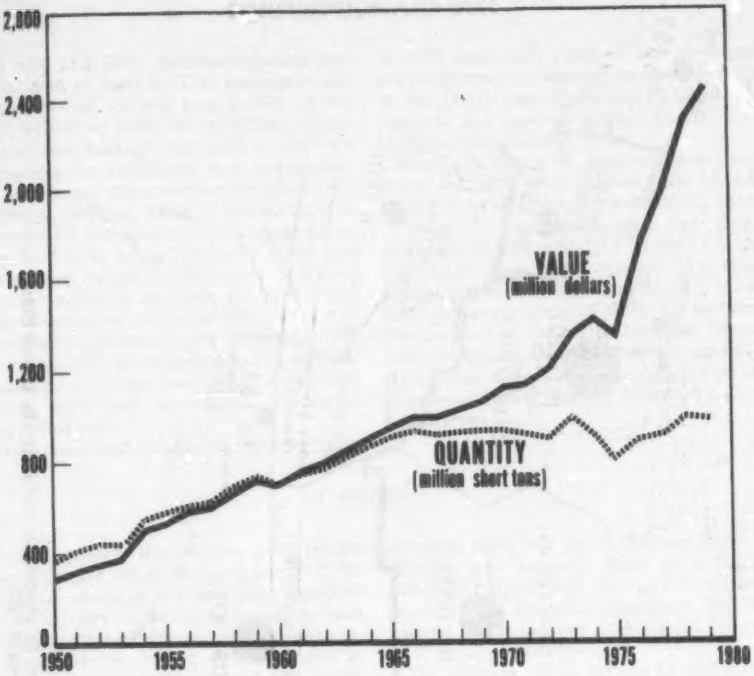


Figure 1.—Production and value of sand and gravel in the United States for 1950-79.

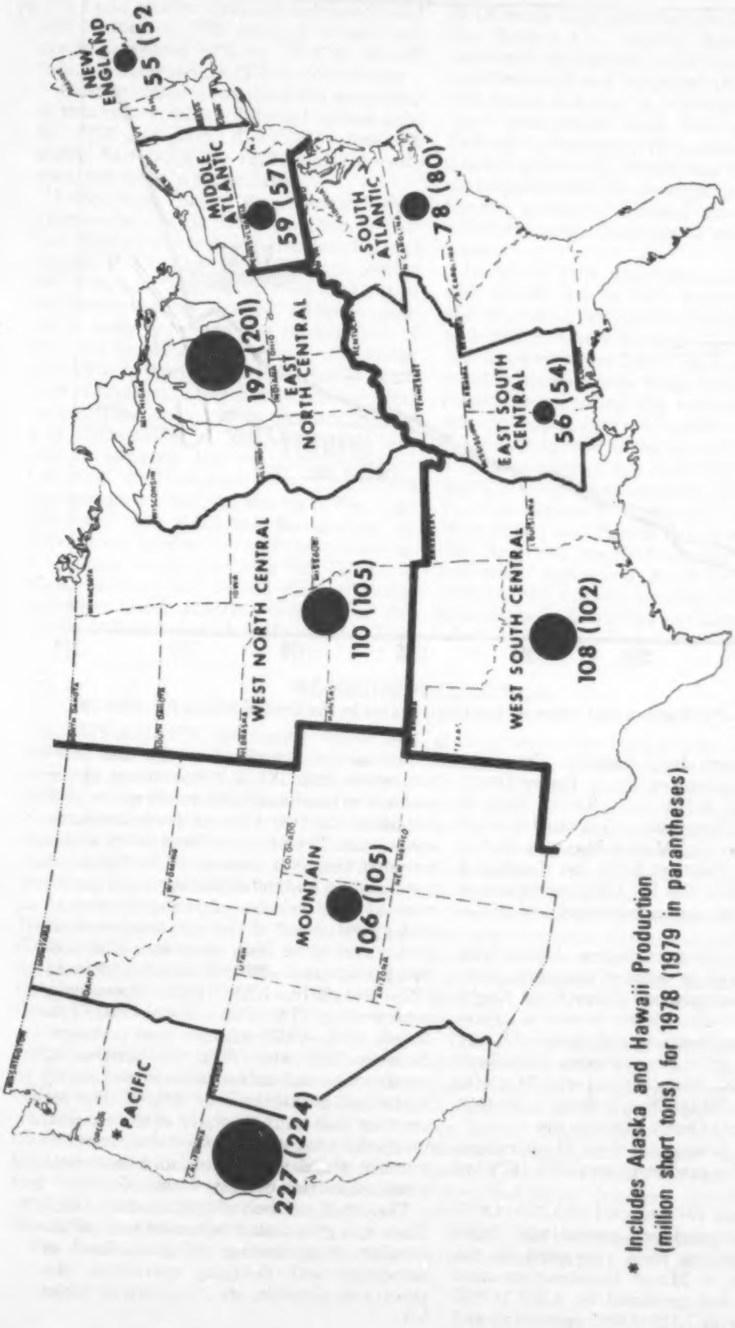
Star Industries, Inc.; Conrock Co., Inc.; American Aggregates Corp.; Dravo Corp.; Gifford - Hill & Co., Inc.; Kaiser Sand & Gravel Corp.; Livingston - Graham Inc.; Owl Rock Products Co.; Martin-Marietta Aggregates; and A. Teichert & Son Inc. Combined production from the 147 (137) operations of the top 10 producers represented 10% of the national total.

The five leading producers of industrial sand and gravel in order of tonnages, were, for 1978, Pennsylvania Glass Sand Corp., Ottawa Silica Co., Martin-Marietta Aggregates, Manley Brothers, and Owens Illinois, Inc.; and, for 1979: Pennsylvania Glass Sand Corp., Ottawa Silica Co., Martin-Marietta Aggregates, Pebble Beach Corp. - Wedron Silica Div., and Owens - Illinois Inc.

Combined production from 27 operations of the top five producers was 45% (42%) of the U.S. total.

In 1978 and 1979, a total of 5,270 (4,975) producers of sand and gravel with 7,249 (6,800) operations were canvassed by the U.S. Bureau of Mines. Construction sand and gravel was produced by 5,219 (4,923) companies with 7,129 (6,684) operations and industrial sand and gravel by 109 (113) companies with 184 (179) operations. Some companies produced both construction and industrial sand and gravel from the same operations. Therefore, a discrepancy exists between the total number of producers of construction and industrial sand and gravel and the total number of producers of sand and gravel. Most of the construction sand and gravel came from operations that produced more than 200,000 tons per year; in 1978 and 1979, 1,204 (1,229) operations, representing 17% (18%) of the total, produced 67% (69%) of the total tonnage. Between 1975 and 1979, the number of construction and industrial sand and gravel operations producing over 200,000 tons per year, as well as their share of the market, increased each year. At the same time, the number of small producers and their combined production decreased (table 6).

The total number of operations in each State and geographic region as well as the number of processing plants on land or associated with dredging operations, stationary or portable, etc., is shown in tables 7-8.


NEW ENGLAND
55 (52)
MIDDLE ATLANTIC
59 (57)
SOUTH ATLANTIC
78 (80)
EAST NORTH CENTRAL
197 (201)
EAST SOUTH CENTRAL
56 (54)
WEST NORTH CENTRAL
110 (105)
WEST SOUTH CENTRAL
108 (102)
MOUNTAIN
106 (105)
*PACIFIC
227 (224)

* Includes Alaska and Hawaii Production
(million short tons) for 1978 (1979 in parantheses).

Figure 2.—Production of sand and gravel by geographic region in the United States in 1978 and 1979.

CONSUMPTION AND USES

In 1978 and 1979, construction sand and gravel sold or used by U.S. producers was about 963 (945) million tons or 97% of the total, valued at $2.05 ($2.14) billion. About 38% of this tonnage was used in concrete aggregates for residential and nonresidential buildings, and construction works for highways, bridges, dams, waterworks, and airports; 5% was used for concrete products such as blocks, bricks, concrete pipes and plaster, and gunite sands; nearly 15% was used for asphaltic concrete aggregates and other bituminous mixtures; 22% (24%) was consumed in roadbases and coverings; 17% (16%) was used as construction fill; and the remaining 3% (2%) was used for railroad ballast, snow and ice control, and other unspecified uses.

Data contained in table 10 indicate that, in 1978 and 1979, most of the sand and gravel for concrete aggregates was produced in the South and West and for asphaltic concrete and roadbase coverings mostly in the North Central and West.

Total production of industrial sand and gravel was 32.8 (33.5) million tons, 2.8 (1.2) million tons of which were exported. Table 14 shows the industrial sand and gravel produced in 1978 and 1979 by uses for the four major geographic regions. The main uses of industrial sand included 44% (43%) for glassmaking and 35% (31%) for foundry. The North Central region lead the Nation in total consumption of industrial sand and gravel with 48% (47%); this region also led in consumption of sand for glassmaking and foundry use.

PRICES

For purposes of this chapter, price means f.o.b. value per ton of sand and gravel at the first point of sale or self-use. This value does not reflect any needed transportation from the plant, yard, or deposit to the consumer. It does, however, reflect those transportation costs needed to bring sand and gravel to the first point of sale or self-use.

Based on this canvass, the average national value per ton of construction sand was $2.01 ($2.14); gravel $2.24 ($2.38); and sand and gravel $2.13 ($2.26). Industrial sand was $7.65 ($8.57); gravel $5.34 ($6.16), and sand and gravel $7.57 ($8.47). For all sand and gravel the national value per ton was $2.31 ($2.47).

National values per ton for major construction sand and gravel uses are given in table 9, and for each State in table 13. Nationally, sand and gravel for concrete products and concrete aggregates had the highest value per ton at $2.48 ($2.65) and $2.43 ($2.59), respectively.

The average values per ton for industrial sand and gravel were much higher than for construction sand and gravel. Starting with 1978 data, table 14 contains, in addition to the national values, the average values per ton and uses for the four major geographic regions. Nationally, industrial sand for filler had the highest value per ton at $26.36 ($31.42), followed by ceramics with $17.35 ($20.45), and hydraulic fracturing sand with $15.61 ($17.27).

FOREIGN TRADE

Construction sand and gravel and industrial sand were exported from the United States, as follows: 800,000 (324,000) tons of construction sand valued at $5.1 ($3.8) million; 625,000 (566,000) tons of gravel valued at $1.6 ($1.2) million; and 2.8 (1.2) million tons of industrial sand valued at $22.6 ($27.5) million. Ninety-two percent (90%) of construction sand and gravel exported went to Canada and the remainder was shipped to 52 (58) different countries. Thirty-three percent (58%) of the industrial sand exported went to Canada, 12% (33%) to Mexico, (22%) to France, and the remainder to 66 (69) other countries.

Of the 579,000 (352,000) tons of construction sand and gravel imported, 89% (99.9%) came from the Canada and the rest from seven (six) other countries. Of the 46,000 (71,000) tons of industrial sand imported, 72% (95%) came from Australia, 18% (4%) from Canada, and the remainder from eight (five) other countries.

TECHNOLOGY

The two major areas of concern for the sand and gravel industry in 1978 and 1979 were again production costs and costs of compliance with Federal and State environmental and safety regulations. Production costs were affected mainly by sharp increases in fuel, power, maintenance, and labor costs, paralleled by no significant increase in productivity. As a result, some sand and gravel producers, mostly of small size, ceased production, were acquired by larger producers, or had to accept a smaller profit margin. The remaining operators tried to improve fuel efficiency and productivity by using more efficient equipment, better planning and design of their operations, computerizing parts of their operations, replacing conventional truck hauling with conveyors, and increasing the size of their operations. The significant trend toward larger operations is shown in table 6. Several articles concerning production problems specific to the sand and gravel industry and applications of new technological solutions in solving them were published in trade magazines.[3]

The costs of meeting present environmental legislation concerning water and air pollution, the working environment, and land reclamation practices have been and will continue to be high.

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Table 2.—Sand and gravel sold or used in the United States, by geographic region

(Thousand short tons and thousand dollars)

Geographic Region	Construction		Industrial		Total	
	Quantity	Value	Quantity	Value	Quantity	Value
1977						
Northeast:						
New England	48,662	95,518	178	2,043	48,834	97,561
Middle Atlantic	54,460	117,208	3,280	22,636	57,740	139,844
North Central:						
East North Central	173,174	327,228	12,740	76,579	185,914	403,806
West North Central	102,313	187,804	1,845	13,526	104,158	201,330
South:						
South Atlantic	67,132	141,056	4,333	30,077	71,465	171,133
East South Central	47,948	96,920	2,329	12,602	50,277	109,523
West South Central	101,423	216,067	3,839	31,062	105,261	247,129
West:						
Mountain	94,054	191,578	848	6,068	94,901	197,646
Pacific	208,729	443,976	1,969	15,989	210,698	460,274
Total[1]	897,900	1,817,000	31,360	210,600	929,200	2,028,000
1978						
Northeast:						
New England	54,890	114,200	185	2,100	55,070	116,300
Middle Atlantic	55,830	130,000	3,640	32,210	59,471	162,200
North Central:						
East North Central	182,900	363,100	14,080	91,940	196,900	455,000
West North Central	108,200	204,000	1,633	12,240	109,900	216,300
South:						
South Atlantic	73,180	158,200	4,673	38,760	77,860	196,900
East South Central	54,920	113,000	1,484	8,708	56,410	121,900
West South Central	104,600	239,800	3,708	32,150	108,300	271,900
West:						
Mountain	104,700	229,600	995	7,536	105,700	237,100
Pacific	224,100	500,800	2,458	23,160	226,600	524,000
Total[1]	963,300	2,053,000	32,850	248,800	996,200	2,302,000
1979						
Northeast:						
New England	52,000	109,600	178	2,173	52,180	111,800
Middle Atlantic	53,480	137,400	3,685	35,370	57,170	172,800
North Central:						
East North Central	186,800	385,200	14,200	102,400	201,000	487,600
West North Central	102,900	200,500	1,651	13,320	104,500	213,800
South:						
South Atlantic	74,230	172,900	5,371	49,700	79,600	222,600
East South Central	52,900	116,800	776	5,511	53,670	122,300
West South Central	97,800	248,000	4,351	43,130	102,200	291,100
West:						
Mountain	104,000	233,900	978	8,659	105,000	242,600
Pacific	221,400	539,400	2,325	23,470	223,700	562,900
Total[1]	945,500	2,144,000	33,510	283,800	979,000	2,427,000

[1] Data may not add to totals shown because of independent rounding.

Table 3.—Percent of sand and gravel sold or used in the United States, by geographic region

Geographic region	Construction		Industrial	
	Quantity	Value	Quantity	Value
1977				
Northeast:				
New England	5	5	1	1
Middle Atlantic	6	7	11	11
North Central:				
East North Central	19	18	41	37
West North Central	12	10	6	6
South:				
South Atlantic	8	8	11	13
East South Central	5	5	8	6
West South Central	11	12	12	15
West:				
Mountain	11	11	3	3
Pacific	23	24	7	8
Total[1]	100	100	100	100
1978				
Northeast:				
New England	6	6	1	1
Middle Atlantic	6	6	11	13
North Central:				
East North Central	19	18	43	37
West North Central	11	10	5	5
South:				
South Atlantic	8	8	14	16
East South Central	6	6	5	4
West South Central	11	12	11	13
West:				
Mountain	11	11	3	3
Pacific	23	24	7	9
Total[1]	100	100	100	100
1979				
Northeast:				
New England	5	5	1	1
Middle Atlantic	6	6	11	12
North Central:				
East North Central	20	18	42	36
West North Central	11	9	5	5
South:				
South Atlantic	8	8	16	18
East South Central	6	5	2	2
West South Central	10	12	13	15
West:				
Mountain	11	11	3	3
Pacific	23	25	7	8
Total[1]	100	100	100	100

[1] Data may not add to totals shown because of independent rounding.

Table 4.—Sand and gravel sold or used in the United States, by State

(Thousand short tons and thousand dollars)

State	1978						1979					
	Construction		Industrial		Total		Construction		Industrial		Total	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Alabama	14,531	31,716	763	3,976	15,294	35,692	13,451	29,944	297	1,375	13,747	31,319
Alaska	69,295	145,271	--	--	69,295	145,271	50,900	104,905	--	--	50,900	104,905
Arizona	28,172	67,896	143	1,200	28,314	69,096	30,520	74,716	W	W	W	W
Arkansas	16,330	33,371	566	3,135	16,896	36,505	15,964	32,594	501	2,605	16,465	35,200
California	112,829	259,984	2,262	21,379	115,091	281,362	127,226	326,109	2,122	21,276	129,348	247,385
Colorado	26,215	56,241	279	2,355	26,493	58,596	25,512	56,263	169	W	25,680	W
Connecticut	10,944	25,417	67	1,140	11,011	26,557	9,990	23,612	W	W	W	W
Delaware	1,449	2,468	--	--	1,449	2,468	1,674	3,281	--	--	1,674	3,281
Florida	20,727	30,720	1,128	6,226	21,855	36,946	20,642	31,145	1,066	8,375	21,708	39,520
Georgia	5,097	10,309	281	2,242	5,378	12,552	5,014	10,792	W	W	W	W
Hawaii	706	1,582	--	--	706	1,582	1,081	3,063	--	--	1,081	3,063
Idaho	7,975	17,677	137	1,617	8,112	19,294	7,719	18,149	W	W	W	W
Illinois	37,657	83,676	5,790	44,238	43,447	127,914	40,033	87,016	5,416	47,174	45,448	134,190
Indiana	27,280	53,030	322	1,345	27,602	54,375	27,050	55,842	W	W	W	W
Iowa	17,672	37,312	W	W	W	W	17,297	37,867	198	1,819	17,495	39,686
Kansas	14,257	24,329	W	W	W	W	14,084	24,780	196	1,710	14,280	26,490
Kentucky	13,177	23,900	W	W	W	W	11,726	23,721	W	W	W	W
Louisiana	21,735	53,049	273	3,032	22,007	56,081	20,446	54,081	W	W	W	W
Maine	11,526	22,467	--	--	11,526	22,467	11,022	20,534	--	--	11,022	20,534
Maryland	13,306	34,947	--	--	13,306	34,947	13,988	39,033	--	--	13,988	39,033
Massachusetts	17,855	37,460	W	W	W	W	16,705	37,164	W	W	W	W
Michigan	42,834	78,939	5,428	28,635	48,262	107,574	44,596	86,635	5,572	29,962	50,169	116,597
Minnesota	31,080	54,967	W	W	W	W	30,939	55,427	W	W	W	W
Mississippi	15,951	33,515	W	W	W	W	16,940	37,797	W	W	W	W
Missouri	14,698	27,281	865	6,378	15,564	33,660	11,699	24,201	859	7,109	12,558	31,310
Montana	6,391	14,230	W	W	W	W	7,012	15,106	--	--	7,012	15,106
Nebraska	16,719	31,906	--	--	16,719	31,906	16,197	33,001	--	--	16,197	33,001
Nevada	10,035	22,622	W	W	W	W	10,498	21,387	W	W	W	W
New Hampshire	7,859	16,295	--	--	7,859	16,295	7,086	15,301	--	--	7,086	15,301
New Jersey	7,941	19,485	2,485	21,354	10,426	40,839	8,277	21,590	2,504	23,092	10,781	44,682
New Mexico	8,239	17,853	--	--	8,239	17,853	7,141	18,245	--	--	7,141	18,245

See footnotes at end of table.

Table 4.—Sand and gravel sold or used in the United States, by State —Continued

(Thousand short tons and thousand dollars)

State	1978						1979					
	Construction		Industrial		Total		Construction		Industrial		Total	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
New York	28,775	59,275	W	W	W	W	26,242	55,889	W	W	W	W
North Carolina	10,454	22,246	992	5,834	11,446	28,080	9,634	21,618	1,569	8,115	11,203	29,733
North Dakota	7,407	17,166	--	--	7,407	17,166	6,648	15,128	--	--	6,648	15,128
Ohio	45,834	100,724	1,315	11,433	47,158	112,157	44,218	104,888	1,726	16,160	45,944	121,048
Oklahoma	10,846	19,056	W	W	W	W	10,496	20,372	1,605	12,129	12,101	32,502
Oregon	19,133	44,510	--	--	19,133	44,510	17,874	45,829	--	--	17,874	45,829
Pennsylvania	19,135	51,243	W	W	W	W	19,047	60,031	1,102	11,709	20,150	71,740
Rhode Island	2,978	6,176	--	--	2,978	6,176	3,537	6,737	--	--	3,537	6,737
South Carolina	7,459	15,356	885	7,173	8,344	22,529	7,332	16,273	989	10,392	8,321	26,665
South Dakota	6,404	11,104	--	--	6,404	11,104	6,001	10,119	--	--	6,001	10,119
Tennessee	11,264	24,017	698	4,613	11,961	28,631	10,778	25,300	431	3,755	11,210	29,056
Texas	55,644	134,305	1,281	15,294	56,925	149,599	50,893	140,955	1,953	26,121	52,846	167,076
Utah	12,585	21,835	W	W	W	W	10,363	18,621	W	W	W	W
Vermont	3,726	6,425	--	--	3,726	6,425	3,660	6,240	--	--	3,660	6,240
Virginia	11,427	29,073	W	W	W	W	11,803	32,268	W	W	W	W
Washington	22,150	49,442	W	W	W	W	24,258	59,382	W	W	W	W
West Virginia	3,264	13,053	W	W	W	W	4,138	18,501	W	W	W	W
Wisconsin	29,253	46,721	1,222	6,291	30,474	53,012	30,879	50,824	1,166	7,752	32,046	58,576
Wyoming	5,101	11,242	--	--	5,101	11,242	5,265	11,419	W	W	W	W
Total U.S.[1]	963,300	2,053,000	32,850	248,800	996,200	2,302,000	945,500	2,144,000	33,510	283,800	979,000	2,427,000

W Withheld to avoid disclosing company proprietary data; included in "Total."

[1] Data may not add to totals shown because of independent rounding.

Table 5.—Sand and gravel production by size of operation in the United States[1]

Sales and use level	Construction				Industrial			
	Number of operations	Percent of total	Thousand short tons	Percent of total	Number of operations	Percent of total	Thousand short tons	Percent of total
1978								
Less than 25,000	2,337	32.8	22,380	2.3	37	22.0	351	1.0
25,000 to 49,999	1,032	14.5	36,240	3.8	33	19.6	1,192	3.6
50,000 to 99,999	1,247	17.5	85,290	8.9	22	13.0	1,602	4.8
100,000 to 199,999	1,303	18.3	177,600	18.4	27	16.0	3,659	11.1
200,000 to 299,999	467	6.6	112,900	11.7	14	8.3	3,544	10.7
300,000 to 399,999	244	3.4	83,900	8.7	10	5.9	3,577	10.8
400,000 to 499,999	139	2.0	61,280	6.4	8	4.7	3,524	10.7
500,000 to 599,999	102	1.4	55,350	5.7	3	1.7	1,622	4.9
600,000 to 699,999	58	.8	37,110	3.9	4	2.2	2,633	8.0
700,000 to 799,999	46	.6	34,450	3.6	--	--	--	--
800,000 to 899,999	33	.5	27,890	2.9	3	1.7	2,531	7.7
900,000 to 999,999	23	.3	21,840	2.3	1	.5	920	2.8
1,000,000 to 1,499,999	60	.8	71,780	7.4	5	2.9	5,985	18.2
1,500,000 to 1,999,999	16	.2	26,780	2.8	1	.5	1,714	5.2
2,000,000 to 2,499,999	5	.1	11,080	1.1	--	--	--	--
2,500,000 and over	11	.2	97,360	10.1	--	--	--	--
Total[2]	7,123	100.0	963,300	100.0	168	100.0	32,850	100.0
1979								
Less than 25,000	2,132	31.9	20,860	2.2	31	19.4	280	.8
25,000 to 49,999	1,009	15.1	36,440	3.9	28	17.5	1,060	3.2
50,000 to 99,999	1,229	18.4	86,660	9.2	25	15.6	1,788	5.3
100,000 to 199,999	1,077	16.1	149,800	15.8	22	13.6	3,149	9.4
200,000 to 299,999	450	6.7	108,300	11.5	12	7.5	2,912	8.7
300,000 to 399,999	258	3.9	87,930	9.0	17	10.6	6,039	18.0
400,000 to 499,999	152	2.3	67,190	7.1	7	4.6	3,107	9.3
500,000 to 599,999	103	1.5	55,760	5.8	4	2.5	2,196	6.6
600,000 to 699,999	53	.9	34,290	3.6	4	2.5	2,603	7.8
700,000 to 799,999	54	.8	40,060	4.6	4	2.5	2,959	8.8
800,000 to 899,999	33	.5	27,630	2.9	--	--	--	--
900,000 to 999,999	21	.3	19,780	2.1	1	.6	995	3.0
1,000,000 to 1,499,999	66	1.1	79,130	8.4	4	2.5	4,711	14.0
1,500,000 to 1,999,999	19	.3	31,450	3.3	1	.6	1,714	5.1
2,000,000 to 2,499,999	10	.1	22,370	2.4	--	--	--	--
2,500,000 and over	10	.1	77,850	8.2	--	--	--	--
Total[2]	6,676	100.0	945,500	100.0	160	100.0	33,510	100.0

[1] An undetermined number of operations leased from the Bureau of Land Management in Alaska are counted as one operation.

[2] Data may not add to totals shown because of independent rounding.

Table 6.—Sand and gravel operations over 200,000 ton per year, in the United States[1]

Year	Construction				Industrial			
	Number of operations over 200,000 tons per year	Percent of total	Total production (thousand short tons)	Percent of total	Number of operations over 200,000 tons per year	Percent of total	Total production (thousand short tons)	Percent of total
1975	928	14	408,300	58	31	25	17,050	75
1976	1,023	14	518,400	62	35	28	19,440	79
1977	1,059	15	566,200	63	42	23	23,540	75
1978	1,204	17	641,700	67	49	29	26,050	79
1979	1,229	18	651,700	69	54	34	27,240	81

[1] An undetermined number of operations leased from the Bureau of Land Management in Alaska are counted as one operation.

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Table 7.—Number of sand and gravel active operations and processing plants in the United States[1]

State	Total number of active operations		Total number of active operations with plants[2]		Active operations with processing plants										Total number of active operations without plants[2]	
					Associated with extraction areas on land						Associated with dredging operations					
					Plants at site				Plants not at site (stationary or portable)		Plants on board		Plants on land			
					Stationary		Portable									
	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979
Alabama	109	100	82	73	34	26	18	15	3	1	7	7	20	24	24	20
Alaska	41	51	17	30	5	4	11	23	--	2	--	1	1	--	24	17
Arizona	153	158	134	132	55	47	64	64	8	11	5	1	2	9	20	14
Arkansas	231	205	138	114	56	40	57	45	6	7	9	9	10	13	94	71
California	402	375	358	307	205	145	123	97	16	9	4	2	10	54	49	44
Colorado	193	200	176	160	44	31	121	101	5	6	--	--	6	22	21	22
Connecticut	146	136	124	106	51	40	69	57	3	4	--	--	1	5	27	26
Delaware	10	9	10	8	3	3	4	4	--	--	1	--	2	1	1	1
Florida	56	51	41	39	8	7	9	9	--	--	8	5	16	18	14	7
Georgia	49	48	40	40	14	17	4	4	3	1	2	--	17	18	8	4
Hawaii	7	6	6	5	4	3	2	2	--	--	--	--	--	--	1	--
Idaho	94	87	81	73	29	27	46	40	5	5	--	1	1	--	15	8
Illinois	197	217	164	174	52	46	69	76	1	2	13	13	29	37	38	36
Indiana	182	182	150	143	65	52	45	48	--	--	8	6	32	37	34	29
Iowa	227	207	172	175	55	62	85	77	1	--	3	3	28	33	26	23
Kansas	168	160	136	127	31	38	62	54	2	3	7	6	34	26	23	24
Kentucky	36	37	30	35	12	13	2	4	4	3	11	12	1	3	1	1
Louisiana	134	118	121	109	20	18	48	42	--	--	16	18	37	31	3	2
Maine	154	154	117	115	27	23	73	77	12	7	1	2	4	6	27	28
Maryland	54	52	43	32	17	16	12	5	6	4	1	1	7	6	9	9
Massachusetts	209	187	169	153	60	59	83	73	11	9	8	4	7	8	32	22
Michigan	345	322	301	234	91	79	176	118	1	3	7	8	26	26	35	25
Minnesota	395	348	355	276	115	75	232	180	3	--	--	1	5	20	37	37
Mississippi	96	101	84	82	37	29	27	31	2	1	6	8	12	13	12	15
Missouri	136	101	126	94	42	28	60	32	2	2	9	9	13	23	10	5
Montana	79	89	72	71	29	23	36	41	5	3	--	--	2	4	7	5
Nebraska	263	237	250	224	80	74	93	90	2	1	28	17	47	42	9	14

Nevada	94	82	72	62	28	22	42	34	1	2	--	--	1	4	20	18
New Hampshire	53	50	52	49	24	30	27	14	1	2	--	1	--	1	1	1
New Jersey	64	60	56	51	33	25	10	16	2	2	--	--	11	8	8	8
New Mexico	91	77	85	74	31	27	48	39	5	5	--	2	1	1	6	3
New York	472	399	408	332	154	127	237	180	9	8	2	8	6	9	63	66
North Carolina	152	151	109	112	42	52	54	47	3	6	2	4	8	3	36	34
North Dakota	85	85	78	60	24	23	53	46	--	--	--	1	1	10	4	3
Ohio	310	298	284	267	181	181	78	65	3	5	2	2	20	14	23	27
Oklahoma	147	121	122	100	49	41	48	35	2	4	2	2	21	18	23	17
Oregon	124	110	114	99	53	50	51	39	2	3	1	1	7	6	8	10
Pennsylvania	142	149	133	129	61	60	54	49	3	5	2	2	13	13	7	18
Rhode Island	25	25	25	22	8	9	13	12	2	--	--	--	2	1	1	4
South Carolina	77	69	47	49	18	22	15	15	2	4	2	2	10	6	12	7
South Dakota	131	132	91	85	8	8	62	57	--	--	5	5	16	15	6	5
Tennessee	92	87	64	58	15	15	27	24	5	2	4	6	13	11	12	12
Texas	236	213	177	158	72	73	61	40	7	8	11	12	26	25	18	10
Utah	73	70	52	52	9	12	36	32	1	1	--	--	6	7	6	5
Vermont	51	45	34	31	5	5	24	21	4	3	1	1	--	1	4	3
Virginia	97	90	59	51	14	17	15	12	10	10	11	8	9	4	15	12
Washington	174	163	122	114	24	31	74	67	5	3	7	6	12	7	8	11
West Virginia	8	8	5	3	3	2	--	--	--	1	2	--	--	--	--	--
Wisconsin	324	322	273	262	46	51	183	178	13	6	6	4	25	23	10	8
Wyoming	61	56	47	38	9	9	23	19	4	1	2	1	9	8	1	3
Total	7,249	6,800	6,006	5,409	2,152	1,917	2,866	2,450	185	165	216	203	587	674	893	794

[1] An undetermined number of operations leased from the Bureau of Land Management in Alaska are counted as one operation.

[2] Based on reports submitted by individual companies.

Table 8.—Number of sand and gravel active operations and processing plants in the United States, by geographic region[1]

Geographic region	Total number of active operations		Total number of active operations with plants[2]		Active operations with processing plants										Total number of active operations without plants[2]	
					Associated with extraction areas on land						Associated with dredging operations					
					Plants at site				Plants not at site (stationary or portable)		Plants on board		Plants on land			
					Stationary		Portable									
	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979
Northeast:																
New England	638	597	521	476	175	166	289	254	33	25	10	9	14	22	92	84
Middle Atlantic	678	608	597	512	248	212	301	245	14	15	4	10	30	30	78	91
North Central:																
East North Central	1,358	1,341	1,172	1,080	435	409	551	485	18	16	36	33	132	137	140	125
West North Central	1,405	1,270	1,208	1,061	355	308	647	536	10	6	52	42	144	169	115	111
South:																
South Atlantic	503	478	354	334	119	136	113	96	24	26	29	20	69	56	95	74
East South Central	333	325	260	248	98	88	74	74	14	7	28	33	46	51	49	49
West South Central	748	657	558	481	197	172	214	162	15	19	38	41	94	87	138	100
West:																
Mountain	838	819	719	662	234	198	416	370	34	34	7	5	28	55	96	78
Pacific	748	705	617	555	291	233	261	228	23	17	12	10	30	67	90	82
Total	7,249	6,800	6,006	5,409	2,152	1,917	2,866	2,450	185	165	216	203	587	674	893	794

[1] An undetermined number of operations leased from the Bureau of Land Management in Alaska are counted as one operation.
[2] Based on reports submitted by individual companies.

Table 9.—Construction sand and gravel sold or used in the United States, by major use[1]

(Thousand short tons and thousand dollars)

Use	1977			1978			1979		
	Quantity	Value	Value per ton	Quantity	Value	Value per ton	Quantity	Value	Value per ton
Concrete aggregate (including concrete sand)	347,447	811,866	$2.34	369,500	898,600	$2.43	357,100	923,000	$2.59
Plaster and gunite sands	--	--	--	9,068	23,760	2.62	10,950	30,400	2.78
Concrete products (blocks, bricks, pipe, decorative, etc.)	53,042	129,260	2.43	41,950	104,000	2.48	32,780	86,940	2.65
Asphaltic concrete aggregate and other bituminous mixtures	132,237	284,204	2.15	141,700	323,800	2.29	142,000	348,000	2.42
Roadbases and coverings	188,843	343,666	1.82	212,500	412,900	1.94	222,400	458,800	2.06
Fill	158,691	210,805	1.33	164,100	232,800	1.42	155,550	240,500	1.55
Snow and ice control	--	--	--	6,974	13,990	2.01	8,207	16,670	2.03
Railroad ballast	1,203	2,751	2.29	1,478	3,460	2.34	1,190	2,489	2.09
Other uses	16,430	34,894	2.12	16,000	39,350	2.46	15,430	41,500	2.69
Total[1]	897,900	1,817,000	2.02	963,300	2,053,000	2.13	945,500	2,144,000	2.27

[1] Data may not add to totals shown because of independent rounding.

Table 10.—Construction sand and gravel sold or used in the

(Thousand short tons

Region	Concrete aggregate (including concrete sand)		Plaster and gunite sands		Concrete products (blocks, bricks, pipe, decorative, etc.)		Asphaltic concrete aggregates and other bituminous mixtures	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1977								
Northeast:								
New England	15,342	36,617	--	--	3,255	8,003	6,896	14,859
Middle Atlantic	18,137	46,036	--	--	3,291	9,207	8,935	19,943
North Central:								
East North Central	64,406	138,362	--	--	9,188	21,152	30,614	58,310
West North Central	35,657	76,657	--	--	6,990	16,081	16,352	29,924
South:								
South Atlantic	33,423	74,737	--	--	8,004	20,020	8,975	19,489
East South Central	20,828	45,825	--	--	5,561	13,705	7,292	14,986
West South Central	54,255	127,721	--	--	8,841	21,100	11,885	26,886
West:								
Mountain	30,679	74,695	--	--	2,390	5,673	14,912	33,631
Pacific	74,721	191,217	--	--	5,513	14,318	26,376	66,227
Total[1]	347,447	811,866	--	--	53,042	129,260	132,237	284,204
1978								
Northeast:								
New England	17,410	43,860	159	484	2,810	6,690	7,953	18,560
Middle Atlantic	19,370	51,770	482	1,712	2,568	7,452	8,301	20,210
North Central:								
East North Central	66,330	145,700	1,290	2,627	7,474	17,471	31,390	63,720
West North Central	40,520	86,710	755	1,854	6,256	13,830	16,070	30,160
South:								
South Atlantic	37,770	85,440	1,290	3,237	5,846	15,400	8,811	22,060
East South Central	24,050	53,260	358	931	2,552	5,975	9,510	21,340
West South Central	55,690	140,000	573	1,381	7,501	18,230	12,480	31,770
West:								
Mountain	36,430	95,820	623	2,058	2,478	7,136	17,580	39,590
Pacific	71,940	196,100	3,538	9,471	4,469	11,860	29,570	76,440
Total[1]	369,500	898,600	9,068	23,760	41,950	104,000	141,700	323,800
1979								
Northeast:								
New England	14,680	38,460	174	478	1,486	3,584	8,771	20,700
Middle Atlantic	16,750	51,790	946	3,124	2,472	8,153	7,453	19,990
North Central:								
East North Central	69,130	156,900	1,234	2,715	6,643	16,160	31,420	65,940
West North Central	35,460	80,080	783	2,276	4,779	10,760	16,150	30,160
South:								
South Atlantic	37,220	90,870	991	3,009	5,294	15,430	9,646	26,730
East South Central	23,140	55,480	1,097	2,456	1,798	4,858	9,130	22,090
West South Central	55,080	157,600	882	2,440	3,561	9,668	11,750	30,110
West:								
Mountain	31,270	85,720	1,245	3,483	2,042	5,732	16,460	39,150
Pacific	74,830	206,100	3,599	10,410	4,708	12,600	31,230	88,130
Total[1]	357,100	923,000	10,950	30,400	32,780	86,940	142,060	343,000

[1]Data may not add to totals shown because of independent rounding.

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United States, by geographic region and major use

and thousand dollars)

Roadbases and coverings		Fill		Snow and ice control		Railroad ballast		Other uses		Total[1]	
Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
11,675	20,186	8,996	11,467	--	--	48	102	2,451	4,285	48,662	95,518
12,943	26,599	9,604	11,419	--	--	280	841	1,269	3,165	54,459	117,210
42,347	74,232	23,424	29,630	--	--	84	219	3,111	5,324	173,174	327,228
27,250	46,020	14,398	16,525	--	--	435	739	1,230	1,857	102,313	187,804
7,358	13,292	7,043	8,636	--	--	61	91	2,268	4,840	67,132	141,056
9,240	15,892	4,396	5,304	--	--	9	17	522	1,190	47,949	96,920
13,214	23,955	12,576	15,181	--	--	32	62	621	1,162	101,423	216,067
31,698	56,020	11,806	14,564	--	--	42	120	3,018	6,875	94,054	191,578
33,019	67,471	66,947	98,079	--	--	211	559	1,940	6,105	208,729	443,978
188,843	343,666	158,691	210,805	--	--	1,203	2,751	16,430	34,804	897,900	1,817,000
13,820	24,240	8,754	11,960	2,309	4,416	95	264	1,577	3,761	54,890	114,200
14,710	32,130	8,116	11,070	1,217	2,762	50	134	1,021	2,774	55,830	130,000
47,610	88,700	24,040	34,700	1,634	3,113	53	219	3,044	6,843	182,900	363,100
28,070	49,320	14,040	17,570	748	1,396	357	578	1,427	2,646	106,200	204,100
7,823	14,860	10,600	13,000	151	371	27	32	1,365	3,781	73,180	158,200
12,520	23,450	5,444	7,015	77	119	11	22	405	1,043	54,920	113,100
16,260	32,190	11,380	14,450	16	47	211	329	409	1,364	104,500	239,700
31,670	59,250	13,730	20,440	406	737	181	413	1,614	4,155	104,700	229,600
40,540	88,790	68,000	102,700	415	1,027	494	1,469	5,142	12,980	224,100	500,800
212,500	412,900	164,100	232,800	6,974	13,990	1,478	3,460	16,000	39,350	963,300	2,053,000
13,300	23,430	9,180	13,290	2,355	4,286	68	238	1,988	5,067	52,000	109,600
14,620	33,200	7,666	11,210	1,889	4,654	56	142	1,717	5,255	53,500	137,400
47,950	98,400	25,300	38,340	1,922	3,362	47	105	3,070	8,237	186,800	385,200
29,000	53,030	13,960	18,620	767	1,653	402	756	1,560	3,189	102,900	200,500
8,522	18,920	10,870	13,220	144	319	27	32	1,506	4,373	74,230	173,000
11,740	22,700	5,537	7,726	79	188	11	22	365	1,241	52,900	116,800
14,460	30,050	11,310	15,500	51	241	74	186	625	2,167	97,800	248,000
38,740	75,910	11,890	18,260	713	1,274	224	588	1,437	3,791	104,060	233,900
44,050	108,100	59,710	104,300	286	694	271	780	3,158	8,179	221,300	539,300
222,400	458,800	155,500	240,500	8,207	16,670	1,190	2,849	15,430	41,500	945,500	2,144,000

Table 11.—Percent of construction sand and gravel sold or used

Region	Concrete aggregates (including concrete sand)		Plaster and gunite sands		Concrete products (block, bricks, pipe, decorative, etc.)		Asphaltic concrete aggregates and other bituminous mixtures	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1977								
Northeast:								
New England	4	5	--	--	6	6	5	5
Middle Atlantic	5	6	--	--	6	7	7	7
North Central:								
East North Central	19	17	--	--	18	16	23	21
West North Central	10	9	--	--	13	13	12	11
South:								
South Atlantic	10	9	--	--	15	16	7	7
East South Central	6	6	--	--	10	11	6	5
West South Central	16	16	--	--	17	16	9	9
West:								
Mountain	9	9	--	--	5	4	11	12
Pacific	21	23	--	--	10	11	20	23
Total[1]	100	100	--	--	100	100	100	100
1978								
Northeast:								
New England	5	5	2	2	7	6	6	6
Middle Atlantic	5	5	6	7	6	7	6	6
North Central:								
East North Central	18	16	14	11	17	17	22	20
West North Central	11	10	8	8	15	13	11	9
South:								
South Atlantic	10	10	14	14	14	15	6	7
East South Central	7	6	4	4	6	6	7	7
West South Central	15	16	6	6	18	18	9	9
West:								
Mountain	10	11	7	9	6	7	12	12
Pacific	19	21	39	39	11	11	21	24
Total[1]	100	100	100	100	100	100	100	100
1979								
Northeast:								
New England	4	4	2	2	5	4	6	6
Middle Atlantic	5	6	9	10	8	9	5	6
North Central:								
East North Central	19	17	11	9	20	19	22	19
West North Central	10	9	7	7	15	12	11	9
South:								
South Atlantic	10	10	9	10	16	18	7	8
East South Central	6	6	10	8	5	6	6	6
West South Central	15	17	8	8	11	11	8	9
West:								
Mountain	9	9	11	11	6	7	12	11
Pacific	21	22	33	34	14	14	22	26
Total[1]	100	100	100	100	100	100	100	100

[r] Revised.

[1] Data may not add to totals shown because of independent rounding.

in the United States, by geographic region and major use

Roadbases and coverings		Fill		Snow and ice control		Railroad ballast		Other uses		Total[1]	
Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
6	6	6	5	--	--	4	4	15	12	5	5
7	8	6	5	--	--	23	r31	8	9	6	6
22	22	15	14	--	--	7	8	19	16	20	18
14	13	9	8	--	--	36	27	7	5	11	10
4	4	4	4	--	--	5	3	14	14	8	8
5	5	3	3	--	--	1	1	3	3	5	5
7	7	8	7	--	--	3	2	4	3	11	12
17	16	7	7	--	--	3	4	18	20	11	11
18	19	42	47	--	--	18	20	12	18	23	25
100	100	100	100	--	--	100	100	100	100	100	100
7	6	5	5	33	32	6	8	10	10	6	6
7	8	5	5	18	20	3	4	6	7	6	6
22	21	15	15	23	22	4	6	18	17	18	17
13	12	9	8	11	10	24	17	9	7	11	10
3	4	6	6	2	3	2	1	9	10	8	8
6	6	3	3	1	1	1	1	3	3	6	6
8	8	7	6	--	--	14	12	3	3	11	12
15	14	8	9	6	5	12	9	10	11	11	11
19	21	42	43	6	7	34	42	32	32	23	24
100	100	100	100	100	100	100	100	100	100	100	100
6	5	6	6	29	26	6	8	13	12	6	5
7	7	5	5	23	28	5	5	11	13	6	6
22	20	16	16	23	20	4	4	20	20	20	18
13	12	9	8	9	10	34	27	10	8	11	9
4	4	7	5	2	2	2	1	10	11	8	8
5	5	4	3	1	1	1	1	2	3	6	5
7	7	7	6	1	1	6	7	4	5	10	12
17	17	8	8	9	8	20	21	9	9	11	11
20	24	38	43	3	4	23	27	20	20	23	25
100	100	100	100	100	100	100	100	100	100	100	100

Table 12.—Construction sand and gravel sold or used in the

(Thousand short tons

State	Concrete aggregates (including concrete sand)		Plaster and gunite sands		Concrete products (blocks, bricks, pipe, decorative, etc.)		Asphaltic concrete aggregates and other bituminous mixtures	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1978								
Alabama	7,889	18,450	--	--	654	1,966	2,475	5,912
Alaska	7,960	40,113	W	W	106	450	3,748	14,948
Arizona	9,911	29,143	182	661	1,091	3,798	4,861	12,505
Arkansas	7,757	17,499	W	226	418	964	1,998	4,477
California	52,148	127,443	3,266	8,846	2,010	5,054	17,755	40,850
Colorado	8,948	24,205	59	246	309	755	4,482	8,356
Connecticut	3,759	10,605	26	92	424	976	2,056	5,286
Delaware	278	746	W	W	W	W	78	168
Florida	11,452	17,665	244	670	1,633	3,197	515	1,420
Georgia	2,994	5,915	W	W	316	774	471	1,602
Hawaii	197	584	--	--	W	W	38	202
Idaho	2,681	6,728	11	57	181	479	998	3,101
Illinois	15,395	37,650	W	36	1,615	4,621	5,583	12,909
Indiana	10,553	22,583	84	136	1,246	2,352	6,222	12,735
Iowa	8,752	20,312	W	497	447	1,131	1,856	3,909
Kansas	4,995	9,347	W	126	1,051	2,321	2,017	3,678
Kentucky	6,014	12,066	W	104	983	1,473	2,280	4,641
Louisiana	11,499	29,917	--	--	1,738	4,068	3,032	9,173
Maine	1,999	5,128	--	--	629	1,616	1,594	3,535
Maryland	7,068	19,867	32	100	1,335	3,275	2,449	5,684
Massachusetts	7,025	17,400	W	226	940	2,300	1,518	3,586
Michigan	13,777	28,857	263	650	2,053	4,356	5,329	9,115
Minnesota	9,282	19,446	240	643	3,072	6,333	4,820	8,175
Mississippi	6,227	13,478	W	W	591	1,517	2,761	6,602
Missouri	8,451	16,314	50	120	617	1,492	1,941	3,909
Montana	2,150	5,856	7	18	86	219	656	1,818
Nebraska	4,745	9,297	144	258	767	1,738	3,396	6,834
Nevada	8,859	9,970	147	385	240	626	1,494	3,581
New Hampshire	2,757	6,515	W	W	245	630	1,649	3,508
New Jersey	3,540	9,703	W	W	320	887	1,001	2,530
New Mexico	3,522	8,475	186	608	377	858	1,014	2,409
New York	8,029	20,463	140	483	989	2,262	4,311	9,796
North Carolina	5,497	11,689	W	W	289	648	2,115	4,964
North Dakota	2,826	8,638	W	W	240	688	1,116	2,219
Ohio	18,669	41,432	497	1,154	2,192	5,383	8,983	20,804
Oklahoma	5,483	10,963	83	118	423	864	1,003	2,021
Oregon	5,005	12,465	74	203	940	2,524	3,912	9,836
Pennsylvania	7,803	21,601	203	760	1,259	4,303	2,959	7,882
Rhode Island	773	1,852	W	W	W	W	667	1,730
South Carolina	3,029	6,543	W	W	462	1,184	1,894	4,758
South Dakota	1,466	3,357	4	13	63	126	919	1,534
Tennessee	3,916	9,266	264	774	324	1,018	1,994	4,183
Texas	30,949	81,554	362	1,037	4,921	12,316	6,449	16,099
Utah	4,091	7,802	W	W	185	380	2,216	4,050
Vermont	1,096	2,356	--	--	209	443	469	907
Virginia	5,310	14,183	167	487	1,549	5,370	771	1,596
Washington	6,632	15,495	198	418	1,413	3,832	4,118	10,600
West Virginia	2,128	8,829	W	W	189	772	518	1,868
Wisconsin	7,935	15,179	432	650	368	759	5,274	8,256
Wyoming	1,270	3,643	18	47	W	W	1,964	3,770
U.S. Total	369,500	898,600	9,068	23,760	41,950	104,000	141,700	323,800

See footnotes at end of table.

United States, by state and major use

and thousand dollars)

Roadbases and coverings		Fill		Snow and ice control		Railroad ballast		Other uses		Total[1]	
Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
2,463	4,165	1,017	1,144	--	--	--	--	32	79	14,581	31,716
2,863	7,538	54,253	81,373	324	606	--	--	W	W	69,295	145,271
6,453	12,576	5,469	8,638	2	5	--	--	203	570	28,172	67,896
5,126	9,072	857	1,023	6	23	W	2	W	86	16,330	33,371
25,532	53,981	7,309	11,252	16	51	193	640	4,600	11,867	112,829	259,984
9,375	17,334	1,868	2,800	295	518	78	196	791	1,831	26,215	56,241
2,212	4,322	1,706	2,224	502	1,115	--	--	261	796	10,944	25,417
811	1,070	167	167	W	W	--	--	--	--	1,449	2,468
1,128	1,439	5,703	6,175	--	--	--	--	51	154	20,727	30,720
377	809	737	866	--	--	--	--	W	W	5,097	10,300
85	151	322	438	--	--	--	--	W	W	706	1,582
3,069	5,717	948	1,408	61	120	--	--	27	68	7,975	17,677
9,244	19,270	5,341	8,078	132	261	W	2	331	948	37,657	83,676
4,322	8,107	4,064	5,686	392	692	7	10	388	728	27,280	53,030
3,395	6,744	2,571	3,757	215	455	W	7	224	499	17,672	37,312
2,827	4,546	2,456	2,966	135	275	W	497	388	573	14,257	34,329
571	1,037	3,062	4,008	71	96	W	17	134	428	13,177	23,900
3,511	7,285	1,840	2,299	--	--	--	--	115	296	21,735	52,049
4,009	6,572	2,135	3,301	614	677	73	239	473	1,198	11,536	22,467
1,286	2,641	659	1,515	W	W	--	--	W	W	13,306	34,947
3,986	6,970	3,235	4,399	850	1,863	W	6	319	699	17,855	37,460
14,482	26,157	5,549	6,959	696	1,175	W	189	W	1,482	42,834	78,939
8,905	14,869	3,778	3,996	244	393	W	26	W	1,097	31,080	54,967
5,618	10,783	657	973	--	--	2	4	W	W	15,951	33,515
2,014	3,327	1,433	1,813	72	144	--	--	119	262	14,698	27,281
2,711	5,036	630	909	40	65	W	204	W	15	6,391	14,230
5,275	10,607	2,342	3,609	16	22	--	--	33	141	16,719	31,306
2,730	5,111	1,339	2,146	8	12	--	--	219	791	10,035	22,622
1,690	3,224	796	1,015	185	295	W	W	492	1,022	7,859	16,295
1,082	2,497	1,782	3,144	67	206	--	--	W	W	7,941	19,485
2,142	4,029	855	985	2	6	--	--	142	483	8,259	17,853
9,147	17,161	4,408	5,142	953	1,958	W	6	W	2,006	28,755	59,275
1,775	2,762	639	836	11	24	W	W	102	271	10,454	22,246
2,341	4,030	783	1,234	16	54	W	W	20	58	7,407	17,166
8,043	18,219	5,873	9,606	370	858	--	--	1,218	3,208	45,843	100,724
1,152	2,044	2,633	2,776	7	17	--	--	62	234	10,846	19,056
6,441	14,915	2,314	3,558	25	72	W	522	W	414	19,139	44,510
4,475	12,472	1,926	2,778	197	598	W	129	W	721	19,135	51,243
724	1,276	407	456	W	W	--	--	--	--	2,978	6,176
256	418	1,181	1,321	W	W	W	27	167	256	7,459	15,356
3,219	5,300	681	794	50	63	--	--	3	16	6,404	11,104
3,868	7,463	706	860	W	W	--	--	W	W	11,264	24,017
6,471	13,784	6,048	8,353	3	7	211	326	194	758	55,600	134,234
4,004	6,798	1,869	2,403	3	4	--	--	W	W	12,585	21,835
1,301	1,875	475	569	143	229	W	2	W	46	3,726	6,425
1,531	4,063	1,479	1,965	66	137	--	--	558	1,252	11,427	29,073
5,624	12,202	3,798	6,031	40	98	W	306	W	459	22,150	49,442
159	639	39	150	2	W	--	--	60	W	3,264	13,053
11,519	16,947	3,216	4,309	103	127	8	18	398	477	29,253	46,721
1,182	2,646	733	1,058	5	W	W	13	15	36	5,101	11,242
212,500	412,900	164,100	282,800	6,974	13,990	1,478	3,460	16,000	39,350	963,300	2,053,000

Table 12.—Construction sand and gravel sold or used in the

(Thousand short tons

State	Concrete aggregate (including concrete sand)		Plaster and gunite sands		Concrete products (blocks, bricks, pipe, decorative, etc.)		Asphaltic concrete aggregates and other bituminous mixtures	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1979								
Alabama	7,281	18,234	W	W	398	1,155	1,949	4,906
Alaska	4,161	20,457	W	W	W	W	392	1,676
Arizona	8,065	25,985	770	1,966	720	2,669	5,270	13,901
Arkansas	7,020	16,435	223	463	157	407	2,469	5,893
California	57,639	150,864	3,360	9,724	2,439	6,388	23,129	64,976
Colorado	7,441	21,700	55	223	276	563	3,888	7,391
Connecticut	3,397	9,409	23	77	280	684	1,804	4,599
Delaware	428	1,087	W	W	W	W	114	258
Florida	11,949	19,200	239	584	869	1,765	868	2,195
Georgia	3,348	6,670	230	418	256	660	360	1,249
Hawaii	66	287	--	--	--	--	334	1,386
Idaho	2,402	6,255	21	85	180	479	755	2,246
Illinois	16,393	37,429	47	150	1,705	4,454	5,967	13,005
Indiana	10,832	25,126	61	124	747	1,574	5,576	11,654
Iowa	7,820	19,127	186	664	367	1,009	1,970	4,087
Kansas	4,305	8,637	W	120	788	1,703	2,422	4,561
Kentucky	6,506	13,449	811	1,643	699	1,533	1,339	2,133
Louisiana	11,023	31,072	--	--	1,515	3,692	3,200	10,172
Maine	1,069	2,720	--	--	233	582	2,061	4,608
Maryland	6,203	18,177	W	W	1,311	3,418	3,335	9,448
Massachusetts	6,027	16,622	83	185	469	1,183	2,098	4,774
Michigan	14,019	32,464	273	658	1,885	4,210	6,572	11,964
Minnesota	9,802	21,172	295	782	2,141	4,598	5,291	8,652
Mississippi	6,187	14,992	W	W	467	1,345	3,780	8,872
Missouri	6,949	15,304	18	52	225	467	2,051	4,265
Montana	1,657	4,592	9	35	85	256	1,073	2,559
Nebraska	3,814	7,526	117	208	1,005	2,189	2,697	5,492
Nevada	4,377	10,002	122	237	184	417	1,803	4,248
New Hampshire	2,473	5,985	43	114	133	388	1,580	3,609
New Jersey	2,922	8,544	232	702	293	805	1,155	3,030
New Mexico	2,765	7,222	209	789	407	954	770	2,069
New York	6,107	16,837	162	571	862	2,173	3,962	9,910
North Carolina	4,799	11,589	128	306	548	1,332	1,628	3,465
North Dakota	1,446	5,008	100	437	201	685	1,113	2,173
Ohio	18,823	44,559	340	884	1,834	4,920	7,915	20,412
Oklahoma	5,640	12,477	273	511	465	1,024	787	2,111
Oregon	3,963	11,527	35	120	1,000	2,760	3,727	10,169
Pennsylvania	7,718	26,405	552	1,851	1,317	5,174	2,336	7,047
Rhode Island	709	1,620	25	100	W	W	619	[illegible]
South Carolina	3,119	7,655	W	W	457	1,144	1,842	4,827
South Dakota	1,329	3,305	4	14	52	104	605	934
Tennessee	3,164	8,803	191	664	265	825	2,062	5,190
Texas	31,399	97,655	386	1,466	1,424	4,546	5,293	12,433
Utah	3,362	6,373	32	50	W	W	1,713	3,584
Vermont	1,006	2,108	W	W	8	21	610	1,321
Virginia	4,738	14,671	125	501	1,632	6,118	676	1,745
Washington	8,505	22,919	199	515	1,233	3,195	3,649	9,919
West Virginia	2,638	11,822	W	W	190	917	825	3,582
Wisconsin	9,061	17,365	513	899	472	1,000	5,393	8,903
Wyoming	1,207	3,587	26	99	W	W	1,189	2,553
U.S. Total[2]	357,100	923,000	10,950	30,400	32,780	86,940	142,000	343,000

W Withheld to avoid disclosing company proprietary data; included in "Total."

[1] Less than 1/2 unit.

[2] Data may not add to totals shown because of independent rounding.

United States, by state and major use—Continued

and thousand dollars)

Roadbases and coverings		Fill		Snow and ice control		Railroad ballast		Other uses		Total[1]	
Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
2,304	3,742	1,387	1,614	W	W	--	--	62	194	13,451	29,944
1,422	3,701	44,596	78,044	205	494	--	--	82	267	50,900	104,905
10,667	21,237	4,625	7,746	W	82	W	14	318	1,017	30,520	74,716
4,836	8,145	1,171	1,505	W	123	W	2	61	122	15,964	32,594
28,625	70,510	9,399	16,490	20	71	142	456	2,472	6,629	127,226	326,109
10,554	20,459	2,237	3,525	406	783	32	103	623	1,516	25,512	56,263
2,148	4,482	1,459	2,196	569	1,276	--	--	311	887	9,990	23,612
870	1,519	208	251	--	--	--	--	--	--	1,674	3,281
2,214	2,845	4,503	4,556	--	--	--	--	--	--	20,642	31,145
398	1,165	353	454	W	W	--	--	W	W	5,014	10,792
362	903	319	479	--	--	--	--	--	--	1,081	3,068
3,491	7,476	579	941	46	49	183	429	63	190	7,719	18,149
10,048	22,143	5,403	8,710	W	223	W	3	353	899	40,033	87,016
4,530	8,694	4,463	7,094	459	861	(1)	1	381	714	27,050	55,842
3,846	7,685	2,636	4,059	182	535	10	27	280	575	17,297	37,867
2,873	4,759	2,729	3,459	154	355	W	497	419	689	14,084	24,780
320	832	1,932	2,712	46	117	W	18	W	284	11,726	23,721
2,866	5,580	1,716	2,204	--	--	--	--	127	362	20,446	54,081
4,285	6,596	2,173	3,565	715	1,046	64	228	423	1,183	11,022	20,534
1,631	4,157	1,807	1,895	4	9	--	--	W	W	13,968	39,033
3,830	7,091	3,075	4,548	713	1,444	--	--	410	1,319	16,705	37,164
15,380	28,366	4,993	6,048	629	846	40	88	806	1,992	44,596	86,635
8,452	13,939	4,117	4,575	257	424	W	35	W	1,251	30,939	55,427
5,472	10,772	932	1,561	1	1	2	4	W	W	16,940	37,797
1,392	2,353	726	1,078	108	238	--	--	231	445	11,699	24,201
3,358	6,218	739	1,273	61	116	W	42	W	15	7,012	15,106
7,010	15,404	1,452	1,921	24	44	W	149	W	67	16,197	33,001
2,813	4,467	1,041	1,671	46	111	--	--	113	235	10,498	21,387
1,292	2,563	731	968	206	277	--	--	629	1,307	7,086	15,301
1,265	2,998	1,958	3,364	284	1,301	--	--	168	845	8,277	21,590
2,339	5,545	571	792	--	--	--	--	80	274	7,141	18,245
8,627	15,969	4,225	5,316	1,360	2,551	11	17	928	2,545	26,242	55,889
1,377	3,220	990	1,216	12	33	W	5	W	433	9,634	21,618
2,318	4,231	1,447	2,498	--	2	W	49	W	45	6,648	15,128
7,104	17,880	6,420	10,881	574	1,225	--	--	1,209	4,126	44,218	104,868
748	1,450	2,565	2,736	11	40	--	--	6	22	10,496	20,372
7,039	17,376	1,771	3,108	18	47	--	--	321	722	17,874	45,829
4,728	14,233	1,483	2,529	245	802	45	126	622	1,864	19,047	60,031
606	1,135	1,180	1,338	W	W	--	--	24	95	3,537	6,737
299	514	1,354	1,682	W	W	W	27	118	136	7,232	16,273
3,110	4,660	853	1,039	42	55	--	--	7	16	6,001	10,119
3,644	7,356	1,286	1,809	19	58	--	--	146	576	10,778	25,300
6,012	13,875	5,860	9,057	W	W	W	W	431	1,662	50,893	140,965
3,168	6,075	1,657	1,694	72	135	--	--	W	W	10,363	18,621
1,136	1,614	563	674	140	221	W	W	193	269	3,660	6,240
1,402	4,205	2,423	3,003	66	128	--	--	741	1,886	11,808	32,268
6,596	15,603	3,623	6,264	42	62	129	323	283	561	24,258	59,382
290	1,298	35	160	--	--	--	--	W	W	4,138	18,501
10,892	16,322	4,078	5,609	144	208	W	13	W	505	30,879	50,824
2,346	4,336	440	618	--	--	--	--	W	W	5,265	11,419
222,400	458,800	155,500	240,500	8,207	16,670	1,190	2,849	15,430	41,500	945,500	2,144,000

Table 13.—Average value per ton for construction sand and gravel

State	Concrete aggregate (including concrete sand)		Plaster and gunite sands		Concrete products (blocks, bricks, pipe, decorative, etc.)		Asphaltic concrete aggregates and other bituminous mixtures	
	1978	1979	1978	1979	1978	1979	1978	1979
Alabama	$2.34	$2.50	--	$1.50	$3.01	$2.91	$2.39	$2.52
Alaska	5.04	4.92	$8.00	9.82	4.23	7.08	3.99	4.29
Arizona	2.94	3.22	3.62	2.55	3.48	3.71	2.57	2.64
Arkansas	2.26	2.34	1.76	2.08	2.30	2.59	2.24	2.18
California	2.44	2.62	2.71	2.89	2.51	2.62	2.30	2.81
Colorado	2.71	2.92	4.17	4.05	2.44	2.04	1.86	1.90
Connecticut	2.82	2.77	3.61	3.40	2.31	2.44	2.57	2.55
Delaware	2.69	2.54	3.91	4.00	2.47	2.50	2.15	2.26
Florida	1.54	1.61	2.74	2.44	1.96	2.03	2.76	2.53
Georgia	1.98	1.99	1.63	1.81	2.45	2.58	3.40	3.47
Hawaii	2.97	4.32	--	--	3.46	--	5.35	4.18
Idaho	2.51	2.60	5.36	4.01	2.65	2.06	3.11	2.98
Illinois	2.45	2.28	2.41	3.16	2.86	2.61	2.29	2.18
Indiana	2.14	2.32	1.62	2.02	1.89	2.11	2.05	2.09
Iowa	2.32	2.45	2.40	3.56	2.58	2.75	2.11	2.07
Kansas	1.87	2.01	2.21	1.92	2.21	2.16	1.82	1.88
Kentucky	2.01	2.07	2.00	2.02	1.50	2.29	2.04	2.34
Louisiana	2.60	2.82	--	--	2.35	2.44	3.03	3.18
Maine	2.57	2.55	--	--	2.57	2.50	2.22	2.24
Maryland	2.81	2.93	3.11	5.00	2.45	2.61	2.32	2.83
Massachusetts	2.48	2.76	2.82	2.22	2.45	2.52	2.37	2.28
Michigan	2.09	2.32	2.47	2.41	2.12	2.23	1.71	1.82
Minnesota	2.10	2.16	2.67	2.65	2.06	2.15	1.70	1.64
Mississippi	2.16	2.42	1.29	1.69	2.57	2.88	2.39	2.35
Missouri	1.98	2.20	2.40	2.88	2.42	2.08	1.96	2.08
Montana	2.72	2.77	2.40	3.84	2.56	3.01	2.77	2.39
Nebraska	1.96	1.97	1.78	1.78	2.27	2.18	2.01	2.04
Nevada	2.58	2.29	2.62	1.94	2.61	2.27	2.40	2.36
New Hampshire	2.36	2.42	2.65	2.66	2.57	2.93	2.13	2.34
New Jersey	2.74	2.92	3.38	3.02	2.77	2.75	2.53	2.62
New Mexico	2.41	2.61	3.27	3.77	2.28	2.35	2.38	3.47
New York	2.55	2.76	3.45	3.53	2.29	2.52	2.27	2.50
North Carolina	2.13	2.41	2.00	2.40	2.24	2.43	2.35	2.14
North Dakota	3.06	3.46	3.80	4.36	2.86	3.41	1.99	1.96
Ohio	2.22	2.37	2.32	2.60	2.46	2.68	2.32	2.58
Oklahoma	2.00	2.21	1.43	1.87	2.04	2.29	2.01	2.66
Oregon	2.49	2.91	2.75	3.48	2.69	2.76	2.51	2.73
Pennsylvania	2.77	3.44	3.74	3.35	3.42	3.93	2.64	3.02
Rhode Island	2.39	2.29	3.50	4.00	2.00	2.80	2.60	2.75
South Carolina	2.16	2.45	1.91	3.67	2.56	2.50	2.51	2.63
South Dakota	2.29	2.49	3.38	3.24	1.99	2.01	1.67	1.55
Tennessee	2.27	2.78	2.98	3.48	3.14	3.11	2.10	2.51
Texas	2.64	3.11	2.86	3.80	2.50	3.19	2.50	2.35
Utah	1.91	1.90	2.76	1.57	2.05	2.06	1.83	2.09
Vermont	2.15	2.10	--	3.15	2.12	2.67	1.93	2.17
Virginia	2.67	3.10	2.91	4.02	3.47	3.75	2.07	2.58
Washington	2.34	2.69	2.11	2.59	2.71	2.59	2.57	2.72
West Virginia	4.13	4.48	4.25	4.85	4.08	4.84	3.90	4.27
Wisconsin	1.91	1.92	1.51	1.75	2.07	2.12	1.57	1.65
Wyoming	2.87	2.97	2.62	3.75	2.10	2.10	2.02	2.15
United States	2.43	2.59	2.62	2.78	2.48	2.65	2.29	2.42

sold or used in the United States, by State and major use

Roadbases and coverings		Fill		Snow and ice control		Railroad ballast		Other uses		Total	
1978	1979	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979
$1.69	$1.62	$1.12	$1.16	--	$1.00	--	--	$2.44	$3.12	$2.18	$2.23
2.63	2.60	1.50	1.75	$2.41	2.41	--	--	1.34	3.24	2.10	2.06
1.95	2.00	1.58	1.67	2.29	1.60	--	$3.14	2.81	3.20	2.41	2.45
1.77	1.68	1.19	1.28	3.96	4.77	$4.50	4.50	2.21	1.98	2.04	2.04
2.11	2.45	1.64	1.75	3.15	3.48	3.31	3.21	2.58	2.68	2.30	2.52
1.85	1.94	1.48	1.58	1.82	1.98	2.51	3.25	2.31	2.43	2.15	2.21
1.95	2.09	1.30	1.51	2.22	2.24	--	--	3.04	2.86	2.32	2.36
1.32	1.75	1.00	1.21	2.42	--	--	--	--	--	1.70	1.96
1.28	1.28	1.08	1.01	--	--	--	--	3.01	--	1.48	1.51
2.15	2.93	1.18	1.29	--	2.38	--	--	3.50	4.33	2.02	2.15
1.79	2.49	1.36	1.50	--	--	--	--	3.18	--	2.24	2.83
1.86	2.14	1.48	1.62	1.96	1.06	--	2.35	2.51	3.03	2.22	2.35
2.08	2.20	1.51	1.61	1.98	1.93	2.29	3.21	2.87	2.54	2.22	2.17
1.88	1.92	1.40	1.59	1.76	1.88	1.32	2.80	1.87	1.87	1.94	2.06
1.99	2.00	1.46	1.54	2.11	2.94	2.32	2.68	2.23	2.41	2.11	2.19
1.61	1.66	1.21	1.27	2.04	2.30	1.50	1.50	1.48	1.65	1.71	1.76
1.82	2.60	1.32	1.40	1.35	2.52	1.96	1.99	3.19	3.05	1.81	2.02
2.08	2.30	1.25	1.28	--	--	--	--	2.49	2.86	2.44	2.65
1.64	1.54	1.55	1.64	1.43	1.46	3.26	3.53	2.53	2.81	1.95	1.86
2.05	2.55	2.30	1.88	3.00	2.06	--	--	4.02	3.84	2.63	2.79
1.79	1.85	1.36	1.48	2.19	2.03	2.76	--	2.19	3.22	2.10	2.22
1.81	1.84	1.25	1.21	1.85	1.34	5.21	2.21	2.09	2.47	1.84	1.94
1.65	1.65	1.06	1.11	1.57	1.65	2.54	3.90	1.72	2.17	1.77	1.79
1.92	1.97	1.48	1.68	--	1.00	2.20	2.20	1.97	2.95	2.10	2.23
1.65	1.69	1.27	1.48	1.99	2.22	--	--	2.29	1.92	1.86	2.07
1.86	1.85	1.59	1.72	1.63	1.91	2.10	2.80	1.00	1.00	2.23	2.15
2.01	2.20	1.28	1.32	1.36	1.83	--	3.74	4.28	1.78	1.91	2.04
1.87	1.59	1.60	1.61	1.52	2.40	--	--	3.61	2.07	2.25	2.04
1.91	1.98	1.27	1.32	1.59	1.34	1.00	--	2.08	2.08	2.07	2.16
2.31	2.37	1.76	1.72	3.05	4.58	--	--	5.20	5.04	2.45	2.61
1.88	2.37	1.15	1.39	3.74	--	--	--	3.41	3.42	2.17	2.55
1.88	1.85	1.17	1.28	2.05	1.88	2.57	1.00	2.58	2.74	2.06	2.13
2.12	2.34	1.31	1.23	2.21	2.72	4.00	4.00	2.65	2.90	2.13	2.24
1.72	1.82	1.58	1.73	3.30	5.00	4.00	4.00	2.90	4.54	2.32	2.28
2.27	2.52	1.65	1.69	2.32	2.13	--	--	2.63	3.41	2.20	2.37
1.77	1.94	1.06	1.07	2.46	3.70	--	5.00	3.78	3.52	1.76	1.94
2.32	2.47	1.54	1.76	2.89	2.60	2.81	--	1.76	2.25	2.33	2.56
2.79	3.01	1.44	1.71	3.04	3.27	2.71	2.76	3.07	3.00	2.68	3.16
1.76	1.87	1.12	1.13	2.50	1.83	--	--	--	3.99	2.07	1.90
1.63	1.51	1.12	1.24	2.00	2.25	1.08	1.00	1.53	1.15	2.06	2.22
1.62	1.50	1.17	1.21	1.26	1.29	--	--	4.92	2.32	1.73	1.69
1.93	2.02	1.22	1.43	3.83	3.05	--	--	2.33	3.94	2.13	2.35
2.13	2.31	1.38	1.55	2.33	5.39	1.55	2.49	3.91	3.86	2.41	2.77
1.70	1.92	1.29	1.02	1.33	1.86	--	--	1.78	1.90	1.74	1.80
1.44	1.42	1.20	1.29	1.59	1.57	1.13	2.80	1.44	1.40	1.72	1.70
2.67	3.00	1.33	1.24	2.07	2.09	--	--	2.27	2.54	2.54	2.73
2.17	2.37	1.59	1.73	2.44	1.92	2.67	2.51	2.16	1.99	2.23	2.45
4.01	4.48	3.88	4.50	3.25	--	--	--	1.94	4.53	4.00	4.47
1.47	1.50	1.34	1.38	1.23	1.44	2.25	2.19	1.20	1.58	1.60	1.65
2.24	1.85	1.44	1.40	1.50	--	2.50	--	2.38	4.38	2.30	2.17
1.94	2.06	1.42	1.55	2.01	2.03	2.34	2.39	2.46	2.69	2.13	2.27

Table 14.—Industrial sand and gravel sold or used by U.S. producers, by geographic region and major use

(Thousand short tons and thousand dollars)

Geographic region	North East			North Central			South			West			United States		
	Quantity	Value	Value per ton	Quantity	Value	Value per ton	Quantity	Value	Value per ton	Quantity	Value	Value per ton	Quantity	Value	Value per ton
1978															
Sand:															
Glassmaking:															
Containers	2,272	19,360	$8.52	2,935	17,650	$6.01	2,584	18,200	$7.04	1,669	15,750	$9.43	9,460	70,960	$7.50
Flat (plant and window)	110	935	8.48	761	4,942	6.50	1,327	9,140	6.89	156	1,190	7.62	2,356	16,200	6.88
Specialty	123	1,119	9.07	144	1,041	7.24	358	2,452	6.95	(*)	2	--	620	4,614	7.44
Fiberglass (unground)	69	563	8.14	465	2,861	6.16	211	1,322	6.27	69	511	7.40	814	5,257	6.46
Fiberglass (ground)	17	353	21.37	342	1,654	4.83	262	3,361	12.85	2	24	12.00	622	5,392	8.67
Foundry:															
Molding and core	538	4,282	7.93	8,112	44,720	5.51	1,247	6,794	5.45	258	1,732	6.71	10,200	57,500	5.66
Molding and core facing (ground)	84	709	8.41	48	467	9.67	--	--	--	--	--	--	133	1,177	8.87
Refactory	43	559	13.04	713	4,586	6.43	83	740	8.96	10	107	10.70	849	5,993	7.06
Metallurgical:															
Silicon carbide	18	103	7.64	297	1,669	5.62	1	6	6.95	60	335	5.58	371	2,113	5.69
Flux for metal smelting	--	--	--	38	448	11.70	14	37	2.75	47	350	7.44	99	835	8.44
Abrasives:															
Blasting	84	781	9.28	129	1,081	8.36	1,476	12,450	8.43	263	1,639	6.23	1,958	15,950	8.17
Scouring cleansers (ground)	2	35	22.51	92	1,470	15.99	82	1,247	15.28	7	46	6.57	182	2,797	15.36
Sewing and sanding	1	22	23.67	100	811	8.12	21	139	6.73	100	1,000	10.00	222	1,972	8.90
Chemicals (ground and unground)	95	809	8.49	243	2,627	10.86	124	1,357	10.83	62	618	9.97	524	5,411	10.31
Filler (ground):															
Rubber, paints, putty, etc	45	1,442	32.10	106	2,024	19.14	76	2,556	33.59	2	33	16.50	230	6,056	26.33
Ceramic (ground):															
Pottery, brick, tile, etc	18	356	19.54	173	2,818	16.27	54	1,043	19.23	7	161	23.00	252	4,378	17.35
Filtration	32	173	5.38	58	423	7.24	89	855	9.56	31	100	3.23	211	1,560	7.35
Traction (engine)	28	213	7.71	105	678	6.45	208	1,132	5.56	53	391	7.38	390	2,414	6.19
Coal washing	9	72	8.30	9	75	8.41	1	10	13.50	--	--	--	18	156	8.56
Roofing granules and fillers	24	292	12.27	18	192	10.84	104	1,596	15.39	44	243	5.52	190	2,324	12.26
Hydraulic fracturing	3	31	10.42	234	2,976	12.71	494	8,229	16.66	110	1,884	17.12	841	13,120	51.61
Other	215	2,119	9.84	581	8,924	15.35	286	2,660	9.30	240	3,364	14.02	1,323	17,070	12.90
Total	3,825	34,300	8.97	15,700	104,100	6.63	9,092	75,330	8.28	3,193	29,480	9.23	31,810	243,200	7.65

Gravel:															
Metallurgical:															
Silicon, Ferrosilicon	--	--	--	--	--	--	448	2,479	5.54	--	--	--	448	2,479	5.54
Filtration	--	--	--	--	--	--	42	163	3.88	208	978	4.70	250	1,141	4.56
Grinding	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Other	--	--	--	7	44	6.13	284	1,650	5.81	51	240	4.68	342	1,934	5.65
Total	--	--	--	7	44	6.13	774	4,292	5.55	260	1,218	4.69	1,041	5,554	5.34
Grand Total[1]	3,825	34,300	8.97	15,710	104,200	6.63	9,866	79,620	8.07	3,453	30,700	8.89	32,850	248,800	7.57
1979															
Sand:															
Glassmaking:															
Containers	2,630	23,820	9.06	2,202	13,330	6.05	2,670	20,539	7.69	1,669	15,950	9.56	9,171	73,640	8.03
Flat (plant and window)	83	792	9.58	517	3,588	6.94	1,023	8,162	7.97	210	1,916	9.12	1,833	14,460	7.89
Specialty	142	1,423	10.01	128	860	6.74	656	4,412	6.72	(4)	1	27.50	926	6,696	7.23
Fiberglass (unground)	--	--	--	910	6,807	7.48	120	1,347	11.19	156	1,252	8.01	1,186	9,406	7.93
Fiberglass (ground)	7	172	24.22	177	2,542	14.33	337	4,954	14.71	--	--	--	521	7,668	14.72
Foundry:															
Molding and core	549	4,964	9.04	7,806	42,710	5.84	1,400	8,937	6.38	222	1,660	7.48	9,479	58,290	6.15
Molding and core facing (ground)	60	480	8.00	17	149	8.69	--	--	--	--	--	--	77	629	8.37
Refactory	32	559	17.71	218	2,725	12.51	31	428	13.94	10	107	10.49	290	3,819	13.42
Metallurgical:															
Silicon carbide	1	14	9.72	332	2,076	6.26	4	35	8.49	13	117	9.10	351	2,242	6.40
Flux for metal smelting	--	--	--	--	--	--	--	--	--	160	1,156	7.20	160	1,156	7.20
Abrasives:															
Blasting	21	205	9.83	236	3,249	13,74	1,662	18,520	11.14	143	1,423	9.93	2,063	23,400	11.34
Scouring cleansers (ground)	1	35	29,72	120	2,074	17.26	75	1,298	17.15	7	46	6.45	204	3,448	16.92
Sawing and sanding	13	93	7.43	61	387	6.37	78	594	7.59	--	--	--	152	1,075	7.09
Chemicals (ground and unground)	95	903	9.62	354	3,216	9.09	149	1,749	11.79	57	548	9.89	655	6,410	9.79
Filler (ground):															
Rubber, paints, putty, etc	19	1,118	57.49	45	1,025	22.59	113	3,467	30.62	1	21	19.02	179	5,631	31.42
Ceramic (ground):															
Pottery, brick, tile, etc	15	319	21.62	103	2,085	20.23	58	1,192	20.72	11	209	19.49	186	3,805	20,45
Filtration	2	16	6.47	69	551	7.98	87	657	7.55	31	111	3.59	190	1,335	7.04
Traction (engine)	23	199	8.66	123	873	7.11	192	1,240	6.46	72	522	7.30	409	2,835	6.92
Coal washing	8	79	9.26	11	96	8.94	39	295	7.58	--	--	--	58	470	8.08
Roofing granules and fillers	24	311	13.12	87	1,321	15.23	99	1,727	17.50	50	316	6.34	259	3,674	14.19
Hydraulic fracturing	2	21	11.76	278	3,882	13.96	546	10,310	18.89	107	1,897	17.74	933	16,110	17.27

Table 14.—Industrial sand and gravel sold or used by U.S. producers, by geographic region and major use —Continued

(Thousand short tons and thousand dollars)

Geographic region	North East			North Central			South			West			United States		
	Quantity	Value	Value per ton	Quantity	Value	Value per ton	Quantity	Value	Value per ton	Quantity	Value	Value per ton	Quantity	Value	Value per ton
1979 —Continued															
Other	186	2,024	14.88	2,210	20,120	9.10	222	2,799	12.59	273	4,065	14.87	2,842	29,000	10.20
Total	3,863	37,550	9,72	15,500	113,700	7.33	9,561	92,650	9.69	3,192	31,320	9.81	32,120	275,200	8.57
Gravel:															
Metallurgical:															
Silicon, ferrosilicon	--	--	--	190	1,378	7.25	824	5,345	6.49	--	--	--	1,014	6,722	6.63
Filtration	--	--	--	11	100	9.45	10	29	3.00	1	3	3.00	21	132	6.22
Grinding	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Other	--	--	--	142	602	4.25	104	312	3.00	110	805	7.30	356	1,720	4.83
Total	--	--	--	342	2,080	6.08	937	5,686	6.07	111	809	7.26	1,391	8,574	6.16
Grand Total[1]	3,863	37,550	9.72	15,850	115,700	7.30	10,500	98,340	9.37	3,303	32,130	9.73	33,510	283,800	8.47

[1] Data may not add to totals shown because of independent rounding.
[2] Less than 1/2 unit.

Table 15.—Transportation of sand and gravel in the United States to site of first sale of use

Method	1978		1979	
	Thousand short tons	Percent of total	Thousand short tons	Percent of total
Truck	856,400	86	848,300	87
Rail	28,060	3	25,520	3
Waterway	19,560	2	26,350	3
Not shipped, used at site	83,080	8	77,090	8
Unspecified	9,056	1	1,761	(1)
Total[2]	996,200	100	979,000	100

[1] Less than 1/2 unit.

[2] Data may not add to totals shown because of independent rounding.

Silicon

By Frederick J. Schottman[1] and Peter H. Kuck[1]

Consumption of silicon alloys and metal increased 7%, based on silicon content, between 1977 and 1978. However, domestic shipments increased only slightly in 1978 because of higher imports. Increased demand in foreign markets during 1979 resulted in lower imports and higher domestic production. Domestic prices rose as much as one-third between 1977 and 1980.

DOMESTIC PRODUCTION

Shipments of silicon metal and alloys by domestic producers increased only slightly in 1978 and 1979. Reflecting changes in demand, the increase was concentrated in the 56% to 95% grades of ferrosilicon and in silicon metal.

In March 1978 Cabot Corp. bought a 64% interest in Kawecki Berylco Industries, Inc. (KBI) by purchasing stock held by Union Oil Co. of California and Pacific Holding Co. Later in the year Cabot acquired the remaining KBI shares held by other owners and merged with KBI. The National Metallurgical Division of KBI produces silicon metal at Springfield, Oreg., while Cabot produces fumed silica from silicon metal at Tuscola, Ill. In May 1978 BOC International, Ltd., acquired control of Airco Inc. by means of a stock tender offer. At that time Airco was producing ferrosilicon and other ferroalloys at Calvert City, Ky., and Niagara Falls, N.Y. The new Airco Division then sold its ferrosilicon operations in July 1979. Airco's two ferrosilicon plants were purchased by SKW Alloys, Inc., a subsidiary of SKW Trostberg, a Federal Republic of Germany company with ferroalloy plants in Canada and the Federal Republic of Germany. In September 1979 South African Manganese Amcor, Ltd. (SAMANCOR) purchased the Roane Electric Furnace Co. plant at Rockwood, Tenn., from Engelhard Minerals & Chemicals Corp. The Rockwood plant has a capacity of 18,000 short tons per year of 50% ferrosilicon and is a significant producer of ferromanganese and silicomanganese.

Table 1.—Production, shipments, and stocks of silvery pig iron, ferrosilicon, and silicon metal in 1978 and 1979

(Short tons, gross weight except as noted)

Alloy	Silicon content (percent)		Producers' stocks-beginning of year	Production	Shipments	Producers' stocks-end of year
	Range	Typical				
1978						
Silvery pig iron	5-24	18	W	W	W	W
Ferrosilicon (includes briquets)	25-55	48	65,312	493,617	462,517	67,583
Do	56-95	76	24,110	164,090	144,540	28,493
Silicon metal (excluding semiconductor grades)	96-99	98	22,172	120,632	129,950	7,418
Miscellaneous silicon alloys (excluding silicomanganese)	32-65	--	17,472	111,826	98,337	11,970
1979						
Silvery pig iron	5-24	18	W	W	W	W
Ferrosilicon (includes briquets)	25-55	48	67,583	564,362	463,852	67,162
Do	56-95	76	28,493	177,472	166,687	26,681
Silicon metal (excluding semiconductor grades)	96-99	98	7,418	147,803	142,621	8,620
Miscellaneous silicon alloys (excluding silicomanganese)	32-65	--	11,970	98,040	80,306	15,533

W Withheld to avoid disclosing company proprietary data.

CONSUMPTION AND USES

Total reported consumption of silicon metal and alloys in 1978 increased 7% based on silicon content, compared with consumption in 1977. However, there was little change in overall consumption between 1978 and 1979. This decrease in the demand growth rate was largely due to lower demand by iron foundries. In both years, consumption of silicon metal in aluminum alloys and in silicones continued to increase at a relatively high rate.

A relatively small tonnage of metallurgical-grade silicon metal is used to produce electronic-grade polycrystalline silicon. Domestic polycrystalline production was estimated to be 800 metric tons in 1978 and 1,000 metric tons in 1979. In order to meet demand for products containing integrated circuits and other semiconductor devices, material manufacturers were forced to stretch polycrystalline capacity and accelerate new wafer plant construction. However, private industry was reluctant to invest in conventional polycrystalline silicon facilities which use the Siemens process because it was convinced that Department of Energy-sponsored, low-cost processes would be commercially available in the near future.

Table 2.—Consumption, by major end use, and stocks of silicon alloys and metal in the United States in 1978 and 1979

(Short tons, gross weight except as noted)

End use	Silvery pig iron	Ferrosilicon[1]				Silicon metal	Miscellaneous silicon alloys[2]	Silicon carbide[3]
Silicon content (percent): Range	5-24	25-55	56-70	71-80	81-95	96-99		63-70
Typical	18	48	65	76	85	98	58	64
1978								
Steel:								
Carbon	1,801	86,231	206	36,877	197	282	10,148	(4)
Stainless and heat-resisting	(5)	22,682	36	23,792	43	294	163	
Full alloy	3,672	29,414	545	12,639	(5)	1,955	1,204	
High-strength low-alloy	--	9,676	(5)	3,623	(5)	20	1,183	
Electric	--	(5)	(5)	36,037	(5)	57	--	
Tool	--	1,365	(5)	1,983	(5)	93	(5)	
Unspecified	1,109	14,917	2,776	--	426	--	62	
Total steel	6,582	164,285	3,563	114,951	666	2,701	12,760	
Cast irons	64,960	214,458	4,283	33,902	1,488	64	99,315	
Superalloys	9	241	--	114	44	83	2	
Alloys (excluding alloy steels and superalloys)	178	6,889	--	315	29	62,544	150	
Silicones	--	--	--	--	--	42,978	--	
Miscellaneous and unspecified	1,618	1,660	--	287	--	3,164	3,148	
Total	73,347	387,533	7,846	149,569	2,227	111,534	115,375	
Percent of 1977	145	99	123	121	66	109	102	
Total silicon content[6]	13,202	186,016	5,099	113,672	1,893	109,303	66,918	
Consumers' stocks, Dec. 31, 1978	6,778	30,737	542	17,039	352	9,341	7,432	
1979								
Steel:								
Carbon	739	95,171	165	34,725	115	429	5,127	289
Stainless and heat-resisting	--	36,013	(5)	22,522	88	199	140	--
Full alloy	1,364	37,591	481	18,972	(5)	2,037	1,172	(5)
High-strength low-alloy	(5)	8,467	--	3,427	--	16	585	--
Electric	--	(5)	(5)	31,341	--	--	--	--
Tool	--	2,111	(5)	1,327	--	81	(5)	(5)
Unspecified	19	16,955	3,577	61	352	--	29	43
Total steel	2,122	196,308	4,223	112,375	555	2,762	7,053	332
Cast irons	59,552	189,539	3,776	31,272	910	225	43,556	49,594
Superalloys	11	285	--	79	27	55	1	--
Alloys (excluding alloy steels and superalloys)	159	7,355	--	143	34	69,427	119	4
Silicones	--	--	--	--	--	51,302	--	--
Miscellaneous and unspecified	196	2,300	--	131	2	3,853	3,491	--
Total	62,040	395,787	7,999	144,000	1,528	127,624	54,220	49,930
Percent of 1978	85	102	102	96	69	114	[4]XX	[4]XX
Total silicon content[6]	11,167	189,977	5,199	109,440	1,299	125,071	31,448	31,955
Consumers' stocks, Dec. 31, 1979	5,673	27,268	490	15,065	304	6,465	5,537	2,718

XX Not applicable.

[1] Includes briquets.

[2] Includes magnesium-ferrosilicon and other silicon alloys.

[3] Does not include silicon carbide for abrasive or refractory uses.

[4] Prior to 1979, data for silicon carbide were included in miscellaneous alloys.

[5] Included with "Steel: Unspecified."

[6] Estimated based on typical percent content.

PRICES

Prices for ferrosilicon, metallurgical-grade silicon metal, and silvery pig iron all increased between 1977 and 1979 in response to inflation and higher energy costs. At the same time, the price difference between each domestic grade and its cheaper, imported counterpart narrowed because of higher demand overseas.

The yearend price of domestic, regular 50% ferrosilicon rose from 33.5 cents per pound of contained silicon in 1977 to 35.5 cents per pound in 1978 and then to 42.0 cents per pound in 1979. Regular 75% ferrosilicon was generally 2 to 4 cents per pound higher than the 50% grade and was priced at 46.25 cents per pound at the end of 1979. The difference between the prices of domestic and imported 75% ferrosilicon decreased over the 2-year period from about 11 cents to 3 cents per pound.

The price of silicon metal followed the ferrosilicon trend. Domestic, lump silicon metal with 1% maximum iron and 0.07% maximum calcium rose from 42.5 cents per pound in 1977 to 49.0 cents per pound in 1978 and then to 56.5 cents per pound in 1979.

FOREIGN TRADE

Exports of ferrosilicon increased 112% by weight between 1977 and 1979, with 59% of the shipments going to Canada. The principal other buyers in the 2 years were Japan (13%), Australia (10%), Mexico (5%), and Angola (3%). Exports of silicon metal rose from 2,404 short tons in 1978 to 4,987 tons in 1979. The total value of silicon metal exports increased accordingly, from $22.0 million to $45.8 million. In 1979, 75% of U.S. silicon metal exports went to Japan. Most of the remainder was shipped to the U.S.S.R. (12%), Ghana (3%), Mexico (2%), and the Republic of Korea (2%).

Total imports of both ferrosilicon and silicon metal increased in 1978 but then decreased in 1979 as stronger demand in foreign markets made exporting to the United States less attractive to foreign producers.

In 1978, the Department of the Treasury found that SKW Electro-Metallurgy Canada, Ltd., had sold silicon metal in the United States at 3.6% below fair value. However, no penalty was assessed when the International Trade Commission found that the imports of Canadian metal had not injured, and were not likely to injure, the domestic silicon metal industry.

In December 1979, the Treasury Department ruled that the Government of Spain had subsidized exports of 75% ferrosilicon and certain other ferroalloys to the United States with tax incentives and credit preferences. Effective January 2, 1980, a countervailing duty of 3.36% ad valorem in addition to the regular duty will be levied by the U.S. Customs Service.

Table 3.—U.S. exports of ferrosilicon

Year	Quantity (short tons)	Value (thousands)
1977	10,548	$6,065
1978	11,900	7,871
1979	22,357	14,740

Table 4.—U.S. imports for consumption of ferrosilicon and silicon metal, by grade and country

Grade and country	1978			1979		
	Quantity (short tons)		Value (thousands)	Quantity (short tons)		Value (thousands)
	Gross weight	Silicon content		Gross weight	Silicon content	
Ferrosilicon:						
Over 8% but not over 30% silicon:						
Brazil	--	--	--	794	137	$302
Canada	4,877	720	$563	3,698	529	272
France	38	8	33	--	--	--
Total[1]	4,915	728	596	4,491	666	575
Over 30% but not over 60% silicon, with over 2% magnesium:						
Brazil	(2)	(2)	(2)	1,773	825	1,385
Canada				2,906	1,374	1,320
France				2,302	1,139	1,875
Germany, Federal Republic of				451	250	748
Italy				443	204	269
Japan				210	95	166
Norway				885	396	615
Venezuela				3,159	1,485	791
Total[1]	(2)	(2)	(2)	12,127	5,768	7,169

See footnotes at end of table.

Table 4.—U.S. imports for consumption of ferrosilicon and silicon metal, by grade and country —Continued

Grade and country	1978			1979		
	Quantity (short tons)		Value (thousands)	Quantity (short tons)		Value (thousands)
	Gross weight	Silicon content		Gross weight	Silicon content	
Ferrosilicon: —Continued						
Over 30% but not over 60% silicon, not elsewhere classified:[2]						
Belgium-Luxembourg	--	--	--	73	44	$71
Brazil	340	161	$217	91	55	90
Canada	28,585	13,638	7,659	6,478	3,098	2,000
Chile	44	22	11	--	--	--
France	4,162	2,128	2,928	2,613	1,486	2,615
Germany, Federal Republic of	847	468	1,768	867	477	1,012
Italy	343	161	211	--	--	--
Japan	1,000	462	796	--	--	--
Norway	1,405	625	907	2,756	1,622	707
South Africa, Republic of	--	--	--	1,472	519	641
Venezuela	8,872	4,161	1,616	--	--	--
Total[1]	45,598	21,826	16,113	14,350	7,298	7,137
Over 60% but not over 80% silicon:						
Argentina	--	--	--	551	408	269
Australia	--	--	--	1,101	782	273
Brazil	7,336	5,290	3,268	15,011	11,032	8,080
Canada	13,857	10,557	5,987	12,507	9,328	6,522
Chile	55	42	19	533	401	212
France	6,099	4,360	3,335	2,744	1,899	2,079
Germany, Federal Republic of	1,242	808	1,701	1,398	910	2,358
Italy	110	71	84	--	--	--
Mexico	56	42	22	--	--	--
Netherlands	14	10	39	--	--	--
Norway	41,190	30,691	13,534	29,050	21,405	13,078
Peru	--	--	--	220	166	105
South Africa, Republic of	1,485	1,099	577	4,124	3,155	1,693
Spain	5,814	4,388	2,019	--	--	--
United Kingdom	414	317	180	--	--	--
Venezuela	1,797	1,348	595	11,481	8,454	6,059
Yugoslavia	5,218	3,984	1,632	3,400	2,412	1,811
Total[1]	84,687	63,007	32,992	82,122	60,352	42,540
Over 80% but not over 90% silicon:						
Canada	291	241	90	406	341	172
Venezuela	--	--	--	57	48	28
Total	291	241	90	463	389	200
Over 90% but not over 96% silicon: Canada	129	120	90	--	--	--
Grand total[1]	135,620	85,922	49,881	113,553	74,473	57,621
Silicon metal:						
Over 96% but not over 99% silicon:						
Argentina	--	--	--	332	NA	222
Canada	8,234	NA	6,653	9,538	NA	8,827
Finland	--	--	--	10	NA	10
France	1,673	NA	1,118	359	NA	294
Germany, Federal Republic of	--	--	--	22	NA	8
Japan	--	--	--	131	NA	81
Norway	3,370	NA	2,147	321	NA	285
Portugal	359	NA	227	--	--	--
South Africa, Republic of	4,980	NA	3,259	4,407	NA	3,512
Spain	1,582	NA	1,011	--	--	--
Switzerland	--	--	--	([3])	NA	33
United Kingdom	([3])	NA	5	131	NA	90
Yugoslavia	8,534	NA	4,905	4,685	NA	3,519
Total[1]	28,732	NA	19,325	19,936	NA	16,831
Over 99% but not over 99.7% silicon:						
Canada	2,308	2,277	1,875	2,750	2,724	2,869
France	397	394	201	--	--	--
Norway	1,654	1,640	1,376	2,538	2,518	2,318
Portugal	110	110	64	--	--	--
South Africa, Republic of	1,769	1,752	1,269	1,761	1,745	1,519
Yugoslavia	1	1	1	--	--	--
Total[1]	6,239	6,174	4,786	7,050	6,987	6,646

See footnotes at end of table.

Table 4.—U.S. imports for consumption of ferrosilicon and silicon metal, by grade and country —Continued

Grade and country	1978			1979		
	Quantity (short tons)		Value (thousands)	Quantity (short tons)		Value (thousands)
	Gross weight	Silicon content		Gross weight	Silicon content	
Silicon metal: —Continued						
Over 99.7% silicon:						
Belgium-Luxembourg	([3])	NA	$14	6	NA	$53
Canada	238		196	214		200
Denmark	3		891	21		3,468
France	19		24	20		284
Germany, Federal Republic of	86		6,120	289		14,826
Italy	56		2,966	95		4,776
Japan	56		640	11		604
Malaysia	([2])		3	--	--	--
Mexico	97		78	--	--	--
Switzerland	([3])		3	--	--	--
United Kingdom	1		70	([3])	NA	16
Total[1]	556	NA	11,005	656	NA	24,225
Grand total	35,527	NA	35,116	27,642	NA	47,702

NA Not available.
[1] Data may not add to totals shown because of independent rounding.
[2] Prior to 1979, magnesium ferrosilicon was included in the class for ferrosilicon with 30% to 60% silicon.
[3] Less than 1/2 unit.

WORLD REVIEW

Brazil.—Production of ferrosilicon in Brazil has increased over 180% since 1972 to 74,000 short tons in 1979, a result of the rapid growth of the national iron and steel industry.[3] Installed capacity in 1977 was 81,400 short tons per year of ferrosilicon and 6,100 short tons per year of silicon metal. If power is available, total capacity is expected to rise to at least 139,000 tons per year by 1982.[3]

Iceland.—The first of two 30-megawatt electric furnaces was brought onstream in April 1979 at the new ferrosilicon plant of Icelandic Alloys, Ltd. The second furnace is expected to be operational by late 1980, and will double the plant's capacity to 55,000 short tons per year of 75% ferrosilicon. The company is owned 55% by the Government of Iceland and 45% by Elkem-Spigerverket A/S of Norway.

India.—Ferrosilicon production fell from 58,300 short tons in 1978 to an estimated 39,000 tons in 1979 because of severe power shortages which were caused by the worst drought in 60 years. A second 11,000-ton-per-year ferrosilicon furnace was commissioned at the Nava Bharat plant in Andhra Pradesh, but it too suffered power cutbacks of up to 30%.[4]

Japan.—In 1977 members of the Ferro-Alloys Association of Japan decided that rising electricity costs were causing the Japanese ferrosilicon industry to lose its competitiveness in the world market. Eleven of the 16 producers agreed to eliminate a total of 110,000 tons per year, or 20% of installed capacity.[5] Japanese production declined from 321,264 short tons in 1977 to 297,681 short tons in 1978 but rose to 352,246 tons in 1979. The power cost increases have apparently caused both Shin-etsu Chemical Industry and Nippon Koshuha Steel Co. Ltd. to withdraw from the ferrosilicon business. Japan Metals & Chemicals Co. Ltd. and Showa Denko KK have stopped production of silicon metal for the same reason.[6]

Norway.—A/S Hafslund Smelteverket, A/S Ila og Lilleby Smelteverket, A/S Bjolvefossen, Elkem-Spigerverket A/S, and Orkla Industrier A/S are all increasing the capacities of their ferrosilicon plants. The 42,000-short-ton-per-year ferrosilicon furnace being built by Orkla Industrier at Thamshavn is scheduled for completion in 1982.[7] Elkem is in the process of doubling its 15,000-ton production capacity for silicon metal at Bremanger Smelteverk.[8]

Philippines.—Maria Cristina Chemical Industries, Inc., produced 12,610 short tons of 75% ferrosilicon in 1978 and planned an integrated quartzite-ferrosilicon project that would double the capacity of its facilities.[9] Electro Alloys Corp. began pro-

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ducing ferrosilicon in the fall of 1979 at its new plant at Manticao on Mindanao and expected to ship 13,000 short tons of 75% grade in 1980.[10]

Venezuela.—Venbozel has broken its ties to Bozel Metallurgie, a subsidiary of France's Nobel Bozel, and changed its name to CVG FeSilven. The Venezuelan ferrosilicon producer operates two new 52-megavolt-ampere furnaces at Matanzas.

Yugoslavia.—Tovarna dusika Ruse is installing a new ferrosilicon furnace at its plant at Ruse in Slovenia. The new furnace will have a capacity of 18,000 short tons per year of 75% grade and is expected to come onstream in mid-1980. The Association of Yugoslav Ferro-Alloy Producers has also announced that another plant with a capacity of 44,000 tons per year is being planned for 1985.[11] Yugoslavia is currently producing about 66,000 tons per year of ferrosilicon.

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[1] Physical scientist, Section of Ferrous Metals.

[2] Anuário Mineral Brasileiro—1978. V. 7, Estatística mineral por substância. Brasilia, p. 198.

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WORLD REVIEW

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Silver

By Harold J. Drake[1]

U.S. mine production of silver declined moderately notwithstanding the sharply increased price of silver during 1979. Consumption also declined moderately, whereas imports and exports were well above the levels of 1978. The annual average price of silver recorded a sharp advance over the comparable price for the preceding year. The increase in price was attributed to speculative interest in silver as a hedge against inflation and the instability of currencies throughout the world. The decline in consumption was led by products containing large quantities of silver per item such as sterlingware, jewelry, batteries, solders, and catalysts. Uses showing increased consumption included photography, electroplated wares, contacts and conductors, and others. Coinage use was well below that of 1978.

Refinery output fell slightly in 1979 as production from ores and concentrates dropped; however, production from old scrap rose slightly, mainly as a result of sharply increased recovery from demonitized coin.

Trading of silver futures on the New York Commodity Exchange (COMEX) and the Chicago Board of Trade (CBT) rose slightly to 34.1 billion ounces[2] while stocks on the exchanges fell to 133.1 million ounces. Industrial stocks fell 44% whereas Treasury

Table 1.—Salient silver statistics

		1975	1976	1977	1978	1979
United States:						
Mine production	thousand troy ounces	34,938	34,328	38,166	39,385	38,055
Value	thousands	$154,424	$149,328	$176,325	$212,681	$422,032
Ore (dry and siliceous) produced:						
Gold ore	thousand short tons	2,251	1,993	3,478	3,499	3,247
Gold-silver ore	do	137	1,027	481	738	756
Silver ore	do	782	794	976	1,102	1,066
Percentage derived from:						
Dry and siliceous ores		35	32	43	55	51
Base-metal ores		65	68	57	45	49
Refinery production[1]	thousand troy ounces	33,073	34,359	36,729	44,018	38,982
Exports[2]	do	32,626	14,596	22,394	22,400	35,563
Imports for consumption[2]	do	66,540	72,700	79,147	75,641	92,381
Stocks Dec. 31:						
Treasury[3]	million troy ounces	41	40	39	39	39
Industry[4]	thousand troy ounces	158,299	146,423	165,343	146,902	149,231
Consumption:						
Industry and the arts	do	157,650	170,559	153,613	160,165	157,258
Coinage	do	2,740	1,315	91	45	168
Price[5]	per troy ounce	$4.418	$4.354	$4.623	$5.401	$11.109
World:						
Production	thousand troy ounces	303,112	[r]316,303	[r]340,213	344,657	344,457
Consumption:[6]						
Industry and the arts	do	[r]376,800	[r]422,100	[r]417,500	404,500	410,000
Coinage	do	38,800	[r]29,700	[r]19,200	29,000	22,800

[r] Revised.

[1] From domestic ores.

[2] Excludes coinage.

[3] Excludes silver in silver dollars.

[4] Includes silver in COMEX warehouses and silver registered in Chicago Board of Trade.

[5] Average New York price. Source: Handy & Harman.

[6] Market economies only. Source: Handy & Harman.

bullion stocks were only slightly below the level of 1978. The national stockpile contained 139.5 million ounces at yearend 1979.

Legislation and Government Programs.—The General service Administration (GSA) proposed to amend The Federal Property Management Regulations by requiring more frequent surveying and reporting by agencies to GSA of their precious-metal-generating activities. GSA also revised the current reporting format to require information on types of silver and other precious-metal-bearing scrap processed or generated, estimates of potential silver recovery, and actions planned to maximize recovery.[3]

DOMESTIC PRODUCTION

Mine production declined moderately in 1979 mainly as a result of processing larger quantities of lower grade ore made economically possible by the higher prices in 1979. Two recently opened mines in Idaho, the Coeur and the DeLamar, operated at near capacity for most of the year. Exploration of new areas and in older closed mines sharply accelerated in 1979. Old mine and mill tailing piles were being processed, usually by heap-leaching, to extract any remaining silver and other precious metals. Byproduct silver from base-metal ores supplied 48% and silver ores 44% of the total output. The remainder mainly came from gold and gold-silver ores. Production in Idaho, which accounted for 46% of total production, decreased moderately whereas production in Arizona, mainly from base metal mining, increased 11%. Of the other principal producing States, increased production was recorded by Montana and New Mexico and decreased production for Colorado, Missouri, and Utah.

The twenty-five largest silver producers contributed 87% of the total output. Nine of these (including the top four) mined silver ores; the others mined base-metal ores and produced byproduct silver. Twelve of the mines produced over 1 million ounces of silver each, which in the aggregate equaled 65% of total production. Domestic mine production was equivalent to 24% of consumption in 1979.

The Sunshine mine of Sunshine Mining Co., in Idaho's Coeur d'Alene silver district regained in 1978 its role as the leading silver producer in the United States only to be displaced in 1979 by the Galena mine located nearby in the same mining district.

ASARCO Incorporated reported production of silver at 4.1 million ounces from the Galena mine and 2.4 million ounces from the Coeur mine, both in Idaho's Coeur d'Alene silver district.[4] The company proceeded with the development of the Troy copper-silver deposit in western Montana. Production is expected by the middle of 1980. The mine is expected to produce 4.2 million ounces of silver per year for about 16 years. ASARCO's silver refinery in Amarillo, Tex., produced 36.1 million troy ounces of silver in 1979, compared with 39.2 million troy ounces in 1978.

Hecla Mining Co., Wallace, Idaho, reported production of 4.1 million ounces of silver in 1979.[5] Hecla's Lucky Friday mine produced 2.8 million ounces, and its shares of the Sunshine mine and the Star-Morning mine totaled 1.1 million ounces and 0.2 million ounces, respectively. The grade of ore milled at the Lucky Friday mine in 1979 averaged 16.4 ounces per ton. Reserves at yearend 1979 totaled 585,000 tons compared with 600,000 tons at the end of 1978. Hecla made plans in 1979 to sink a new shaft 7,500 feet to increase capacity at the Lucky Friday mine by 35% and to accelerate exploration of geologically favorable areas surrounding the mine. Hecla Mining headed a joint venture to lease the mining properties of the Consolidated Silver Corporation near Osborn, Idaho. The main shaft on the property will be rehabilitated and deepened followed by extensive exploration from its bottom. Known ore reserves of about 1.3 million ounces in the upper levels of the property will be mined concurrently with the exploration program.

Homestake Mining Company reported production of 1.4 million ounces of silver from its Bulldog silver mine near Creede, Colo.[6] This level of production was 0.7 million ounces below that of 1978, which reflected partly the processing of lower grade ore and partly a reduction in the tonnage milled. Ore reserves in the Bulldog mine at yearend 1979 totaled 385,375 tons averaging 17.3 ounces of silver per ton.

Earth Resources Company produced 1.9 million ounces of silver at its DeLamar silver-gold mine near DeLamar, Idaho.[7] The company planned to sell its mining group, consisting essentially of the DeLamar mine, to Dome Mines Limited of Canada but the plan was terminated for a number of reasons. A second pit, the North DeLamar, was opened and began supplying ore to the mill.

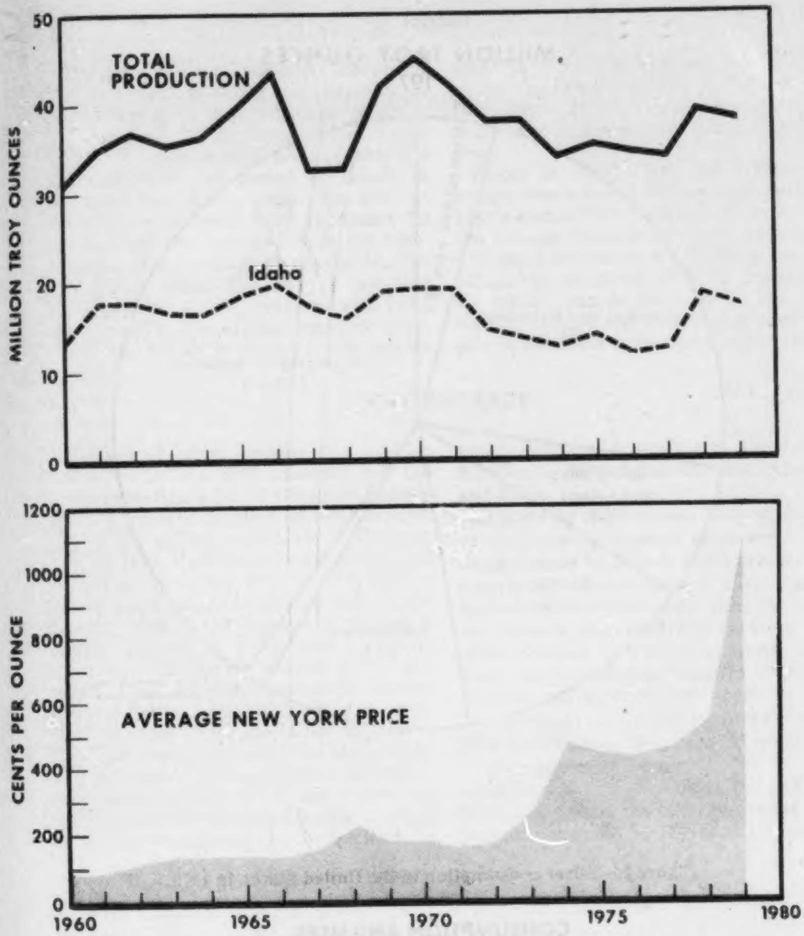

Figure 1.—Silver production in the United States and Idaho and price per ounce.

Day Mines Inc. (DMI), Wallace, Idaho, reported silver production from its Leadville Unit (Sherman Tunnel) in Colorado totaled 1.2 million ounces in 1979.[8] Production from DMI's Republic, Washington gold-silver mine in 1979 totaled 43,947 tons averaging 0.37 ounces of gold and 1.23 ounces of silver per ton of ore. DMI also shared in the production of the Coeur and the Galena silver mines in Idaho, and acquired the Victoria copper-silver mine in Elko County, Nev., and commenced rehabilitating it preparatory to its reopening.

Phelps Dodge Corporation reported 2.4 million ounces of byproduct silver was produced during the company's domestic copper-mining operations.[9] Production of silver at Inspiration Consolidated Copper Company's Black Pine silver mine at Philipsburgh, Mont., totaled 624,000 ounces, which came from a 1.6 million ton ore body averaging 6.2 ounces of silver per ton.[10]

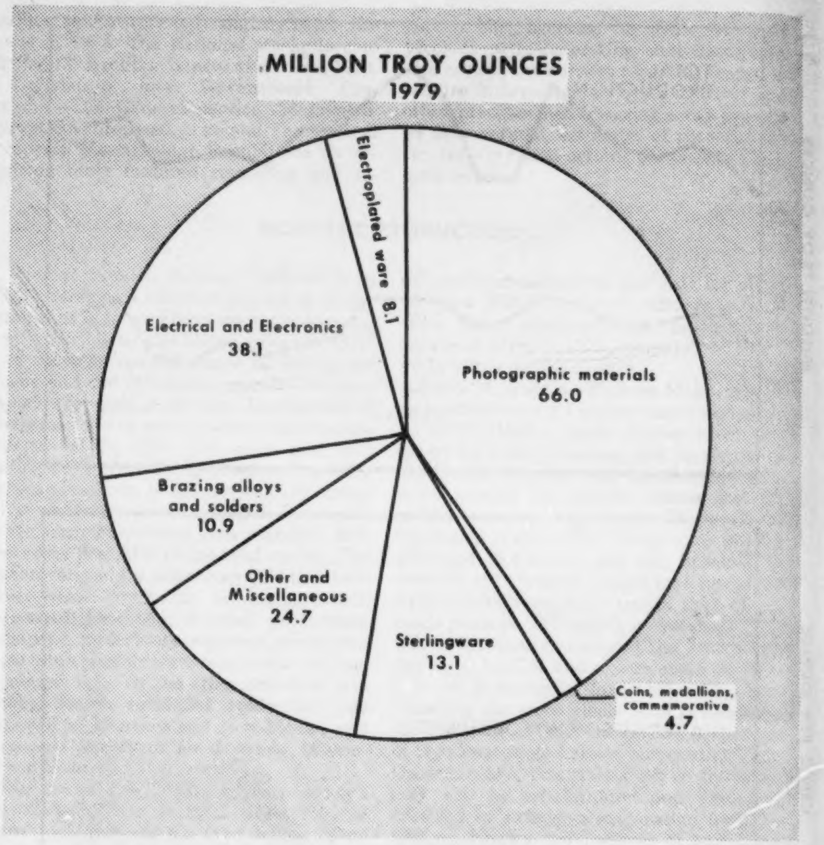

Figure 2.—Silver consumption in the United States, in 1979.

CONSUMPTION AND USES

Industrial consumption of silver declined slightly in 1979 primarily as a result of rising silver prices and declining business activity. The decline in silver demand was most pronounced in the latter part of the fourth quarter when the acceleration in the price of silver was the sharpest. Sterlingware and jewelry were most noticeably affected as demand for silver in their manufacture fell 25%. Use of silver in catalysts dropped 31%. Nearly all other uses recorded gains in consumption during 1979. Sterlingware, jewelry, and catalysts, in the aggregate, accounted for 15% of total consumption in 1979 compared to 21% in 1978.

STOCKS

Total accountable stocks at yearend 1979 were 333.4 million ounces, a level virtually unchanged from that of 1978. Refiner, fabricator, and dealer stocks fell 44%; whereas, silver stocks in registered vaults of COMEX recorded a 28% gain. Silver bullion held by the CBT and the Department of Defense fell slightly. The strategic stockpile contained 139.5 million ounces, all of which has been declared surplus to national defense needs. Although a number of bills have been introduced in the Congress to dispose of all or part of this silver, none have been passed.

PRICES

The price of silver advanced sharply in 1979 as a result of strong speculative interest in silver metal as a hedge against rising inflation and the declining value of the dollar. The average daily price in cents per ounce of silver, as quoted by Handy & Harman, New York, began the year at 596.6, fell to the low of 596.1 on January 11, and finished the year at 2800.0, the high. The gain in the average daily price in 1979 was 2203.4 cents. The average monthly price was 1109.4 cents compared with 540.1 cents in 1978. The average monthly price, which was 625.48 for January, rose moderately to 933.4 for August then jumped sharply in October to 1678.1 and again in December to 2179.3. The year ended with no abatement in the upward pressure on the price.

Prices on the London Metal Exchange ranged from a low of 593.7 cents on January 15 to a high of 3209.8 cents on December 31. The average for 1979 was 1110.9 cents.

Trading volume on the COMEX was 20.4 billion ounces during 1979, an increase of 0.7 billion ounces from 1978. The CBT trading volume was 13.7 billion ounces, a gain of 0.4 billion ounces over that of 1978.

FOREIGN TRADE

Exports of silver totaled 35.6 million ounces in 1979, a 59% increase over the comparable figure for 1978. Refined bullion, which accounted for 46% of total exports, totaled 16.3 million ounces, a level 63% over that of 1978. Exports of waste, scrap, and sweepings increased 73% to 17.0 million ounces which was equivalent to 48% of total exports. Most of the increase in exports of bullion and waste, scrap, and sweepings occurred in the last few months of 1979 as a result of the increased speculative interest in silver for the former and lack of domestic refining capacity for the latter. Exports of doré and precipitates declined moderately. The remainder of the exports consisted of very minor quantities of silver ore and concentrates. The principal foreign markets for bullion were Japan and Switzerland; for waste, scrap, and sweepings, the United Kingdom, Belgium-Luxembourg, Canada, and Japan.

Imports for consumption of silver increased 22% mainly because shipments of refined bullion in March and October were sharply higher than those of other months. Refined bullion, which accounted for 85% of the imports, increased 28% to more than offset declines in imports of waste, scrap, doré, and precipitates. Imports of ore and concentrates were slightly higher in 1979. The principal sources for imported silver in 1979 were Canada, Mexico, and Peru which, in the aggregate, supplied 78% of total imports and 79% of bullion imports. The United Kingdom, the other major source of bullion, accounted for 11% of total imports.

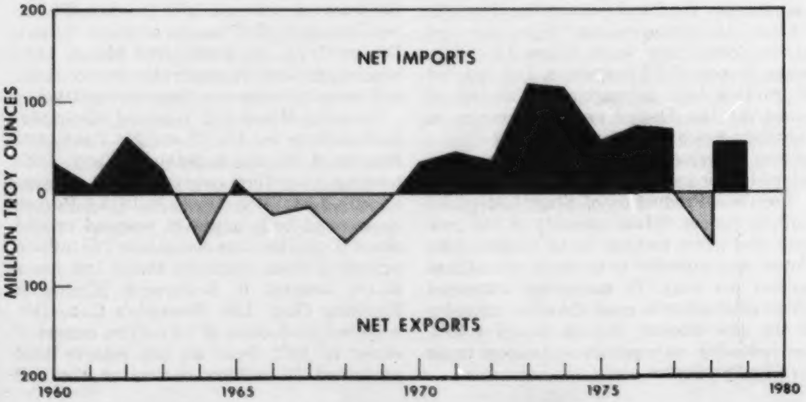

Figure 3.—Net exports or imports of silver, 1960-79.

WORLD REVIEW

World mine production of silver in 1979, including centrally planned economy countries, decreased slightly to 344.5 million ounces. The United States, Canada, Mexico, and Peru accounted for 49% of world output, the U.S.SR. 13%, Australia and Poland, 7% each. The remainder came from numerous other countries.

World comsumption of silver in 1979 for industrial and coinage uses, exclusive of centrally planned economy countries, totaled 432.8 million ounces compared with 433.5 million ounces in 1978.[11] A 1.4% increase in industrial use, which accounted for 95% of total use in 1979, was accompanied by a 21.4% decrease in use of silver in coinage. Total consumption by market economy countries exceeded newly mined supply by 162 million ounces, according to Handy & Harman estimates. Secondary production supplied 50% of the difference; outflow from Indian stocks, 21%; demonetized coin, 9%; and United States, foreign government and private stocks, the remainder.

Australia.—Production of silver rose slightly to 25 million ounces. The Woodlawn mine in New South Wales was dedicated and commenced operating late in 1978. The open pit mine is expected to produce about 0.9 million ounces of silver per year, in addition to large tonnages of copper, lead, and zinc, for about 10 years. The mine is operated as a joint venture between Phelps Dodge Corporation and subsidiaries of St. Joe Mineral Corporation and Conzinc Riotinto of Australia, Ltd., with each having an equal interest. M.I.M. Holdings Limited, reported silver production from the Mount Isa mine for the fiscal year ending June 30, 1979 at 14.6 million ounces.[12] Silver reserves at the Cobar, New South Wales, Lead-zinc-silver deposit of EZ Industries, Ltd., totaled 27 million tons averaging 4.2 ounces of silver per ton. Design and construction of the mine has been deferred until the price of zinc, a major metallic constituent of the ore body, has improved.

Bolivia.—Production of silver totaled 5.7 million ounces. Silver capacity of the new lead and silver smelter to be located near Potosi was expected to be about 6.5 million ounces per year. To encourage increased silver production to meet the silver capacity of the new smelter, Bolivia passed a 50% tax reduction on royalties and export taxes on silver producers.

Canada.—Mine production of silver decreased 6% to 3.1 million ounces. Canadian reserves of silver and other metals were reviewed.[13] The review presented a detailed study of silver reserves by mine or deposit by Province and listed tonnages and grade of ore. Exploration in the Kathleen Lake area north of Mayo, Yukon Territory, by Prism Resources, Ltd., revealed extensive high-grade silver and base-metal mineralization in several contiguous areas. Channel sampling yielded silver concentrations ranging from 10 ounces per ton to 176 ounces per ton, the tonnage of which had not been delineated.

Production of silver at the Kidd Creek mine of Texasgulf Canada Ltd. totaled about 6 million ounces, about 11% above that of 1978.[14] At yearend, the mine contained a 214-million-ounce silver reserve above the 5000 foot level. Ore reserves below the 5,000 foot level had not been delineated at yearend. Exploration continued to find ore so that the ultimate depth or lateral extension of the deposit had not been determined at yearend. Texasgulf Inc. continued exploring its large base-metal sulfide deposits at Izok Lake and Hood River, Northwest Territories.

Mine production of silver in 1978 by United Keno Hill Mines, Ltd., fell 2% to 2.7 million ounces.[15] Ore reserves increased from 126,000 tons averaging 40 ounces of silver per ton to 246,000 tons averaging 31 ounces per ton. Silver production at the Sturgeon Lake mine, a joint venture between Sturgeon Lake Mines, Ltd., and Falconbridge Copper Ltd., was 1.9 million ounces, a 14% decrease from that of 1979.[16] Reserves at yearend 1978 totaled 599.000 tons averaging 5.17 ounces of silver per ton. During 1978, Sturgeon Lake Mines, Ltd., was merged into Falconbridge Copper, Ltd., and ceased to exist as a corporate entity.

Noranda Mines Ltd. reported silver production from the No. 12 and No. 6 mines of Brunswick Mining & Smelting Corp., Ltd., totaling 5.3 million ounces in 1979 compared with 5.1 million ounces in 1978.[17] Proven reserves at both mines at yearend totaled about 69 million tons containing 195 million ounces of silver. Noranda Mines Ltd. has a 64.1% interest in Brunswick Mining & Smelting Corp. Ltd. Noranda's Geco Div. reported production of 1.9 million ounces of silver in 1979 from an ore reserve that contained 34 million ounces at the end of the year. Production of silver by Mattabi Mines Ltd. totaled 2.1 million ounces in 1979. Ore reserves of the mine totaled 11 million ounces at the end of 1979. Noranda Mines Ltd. has an operating interest in the mine.

Placer Development, Ltd. has joined Equity Mining Corporation to exploit the Sam Goosley silver-gold-copper property located at Houston, British Columbia. The property was estimated to contain 38 million tons of ore containing 3.1 ounces of silver per ton. Production was planned at 5.7 million ounces of silver per year. Placer Development, Ltd., will be responsible for financing, constructing, and operating the mining and processing facilities.

Chile.—St. Joe Mineral Corp. decided to develop the El Indio gold-silver-copper deposit in northeastern Chile with a proven reserve of 2.2 million tons of ore averaging 4.4 ounces of silver per ton.[18] The mine is expected to begin operating early in 1981 and reportedly will produce about 1.7 million ounces of silver per year.

Dominican Republic.—Rosario Dominicana, S.A., a subsidiary of Rosario Resources Corp., operated its Pueblo Viejo gold-silver mine near capacity in 1978.[19] Production of precious metals totaled 1.8 million ounces of silver and 336,073 ounces of gold. Reserves of oxide ore totaled 19.2 million tons containing 12.9 million ounces of silver and 2.3 million ounces of gold. The sulfide ore reserve contained 17.7 million ounces of silver and 2.4 million ounces of gold, but a satisfactory metallurgical process to treat the sulfide ore still had not been developed. On October 18, 1979, the Dominican Republic purchased Rosario's interest in the mine for approximately $35 million.

Honduras.—Production of silver in 1979 at the El Mochito mine of Rosario Resources Corp. totaled 2.2 million ounces.[20] Ore reserves at yearend totaled 7.9 million tons containing 35.2 million ounces of silver in addition to gold, lead, zinc, and copper.

Mexico.—Mine production of silver in 1979 totaled 49.3 million ounces, a level well below that expected to result from extensive expansion of silver mines and plants of recent years. Production had been expected to increase to about 60 million ounces by the end of 1979.

Lacana Mining Corp. reported silver production at the Las Torres complex in 1979 totaled 5.0 million ounces from ore reserve that at yearend contained 26.5 million ounces of silver.[21] Silver production at the Encantada mine in 1979 totaled 1.4 million ounces. At yearend, silver reserves totaled 22.7 million ounces. Annual production at the La Encantada mine is expected to be 3.2 million ounces when operated at full capacity.

Expansion of the Huautla silver-lead mine in Morelos by Rosario Mexico, S.A. de C.V. was largely completed in 1978.[22] Silver production in 1979 totaled 0.7 million ounces. At yearend, silver reserves stood at 4.4 million ounces. A modernization and improvement program at the Tayoltita silver and gold mine operated by Minas de San Luis, S.A. resulted in a 25% increase in production with the same labor force.[23] Annual production is now about 1.8 million ounces from ore averaging about 11 ounces of silver per ton.

Nicaragua.—Rosario Mining of Nicaragua Inc., a subsidiary of Rosario Resurces Corp., continued to explore the area around the Rosita mine and a large low-grade deposit of silver and gold in the Coco River area.[24] The Rosita mine area produced 444,500 ounces of silver from an ore reserve containing 1.3 million ounces. The Nicaraguan Government nationalized the mining industry in November of 1979, but terms for compensating Rosario Resources for its mineral holdings had not been determined at yearend.

South Africa, Republic of.—Black Mountain Mineral Development Company, Ltd., continued to develop the Broken Hill ore body, one of three large contiguous lead, zinc, copper and silver deposits located near Aggeneys, northwestern Cape Province.[25] In the aggregate, the three deposits contain about 600 million ounces of silver. The property is expected to come onstream early in 1980 and produce about 4 million ounces of silver per year. Gold Fields of South Africa, Ltd., owns a 51% interest and is manager of the project.

TECHNOLOGY

Scientists at the U.S. Bureau of Mines Reno (N.ev) Metallurgy Research Center reported on a method to recover silver and gold from ore bodies too small, or too low in grade for conventional recovery technology.[26] The basic recovery technique is circulating a dilute cyanide solution through heaps of ore to dissolve precious metals, which are then recovered by passing the solutions through columns of activated carbon. The technique is simple and has exceptionally low processing and capital costs. The Bureau of Mines investigated the applicability of carbon-in-pulp process for recovering silver from low-grade ores.[27] The research developed a practical procedure for the design of carbon-in-pulp adsorption circuits using leach slurry equipment.

Another method of silver recovery investigated by Bureau of Mines scientists was ferrous chloride-oxygen leaching of sulfide concentrates containing silver and base metals.[28] The investigation revealed that 99.7% of the silver in the test sulfide concentrate was recovered. The U.S. Geological Survey reported on the metal in the ash content of incinerated sewage sludge developed in Palo Alto, Calif.[29] Incineration of the sludge develops about 2,000 tons of ash per year, which contains 660 parts per million of silver, 30 parts per million of gold, and large quantities of other metals, all of which constitutes a valuable resource.

A new technique using silver as a catalyst in ferric sulfate oxidative leaching of copper sulfide ore concentrates was developed.[30] A small quantity of silver catalyst added to the leach solution increased significantly the rate and extent of leaching and copper recovery from a chalcopyrite concentrate. Numerous methods to remove silver from leach solutions were developed. In one method, the solution was treated with aqueous sodium sulfide or hydrogen sulfide to precipitate silver sulfide, which is then desulfurized by an oxidizing roast.[31] In another method, the leach solution is contacted with an amalgam of mercury and lead, copper or other suitable metals, at which time the silver replaces the metal to form a silver-mercury amalgam from which the silver is easily extracted.[32] Another solution used to leach a complex precious metal sulfide ore was treated with activated carbon to absorb the gold and iodine to precipitate the silver.[33] In the electrolytic recovery of silver and gold directly from ore, the use of sodium cyanide and a electroconductive cationic resin such as polybenzyltrimethylammoniumchloride improved the rate of recovery and the quality of the recovered metal.[34] Silver was recovered separately from an ammonium sulfate solution used to leach silver-bearing scrap by treating the leach solution with hydrogen gas at optimum pressure.[35]

Metallurgical experimentation of bulk flotation circuit treating a complex basemetal ore containing significant quantities of silver, resulted in a new system that increased silver recovery from about 70% to over 80%.[36] Soda ash was substituted for part of the lime used to raise the pH from 6.0 to 8.0 and the standard sodium cyanide dosage, which was found to have dissolved part of the silver in the ore and carried it into the mill tailings pond, was reduced to achieve the improved recovery rate. Silver was recovered from a silver sulfide ore by mixing sodium cyanide or potassium cyanide with the ore in an aerated bed at tempertures of 10 ° to 40 ° C for 12 to 48 hours, then slurrying with water and filtering the slurry to recover silver.[37]

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[1] Physical scientist, Section of Nonferrous Metals.

[2] Ounce as used throughout this chapter refers to the troy ounce.

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[7] Earth Resources Company. 1979 Annual Report. 28 pp.

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Table 2.—Mine production of recoverable silver in the United States, by month

(Thousand troy ounces)

Month	1978	1979
January	3,478	3,268
February	3,253	3,070
March	3,659	3,327
April	3,285	3,244
May	3,230	3,358
June	3,300	3,256
July	2,662	3,214
August	3,415	3,498
September	3,092	2,906
October	3,395	3,065
November	3,249	2,897
December	3,367	2,957
Total	39,385	38,055

Table 3.—Twenty-five leading silver-producing mines in the United States in 1978, in order of output

Rank	Mine	County and State	Operator	Source of silver
1	Sunshine	Shoshone, Idaho	Sunshine Mining Co	Silver ore.
2	Galena	do	ASARCO Incorporated	Do.
3	Lucky Friday	do	Hecla Mining Co	Do.
4	Coeur	do	ASARCO Incorporated	Do.
5	Berkeley Pit	Silver Bow, Mont	The Anaconda Company	Copper ore.
6	Utah Copper	Salt Lake, Utah	Kennecott Copper Corp	Do.
7	Bulldog Mountain	Mineral, Colo	Homestake Mining Co	Silver ore, silver tailings.
8	DeLamar	Owyhee, Idaho	Earth Resources Co	Gold-silver ore.
9	Sherman Tunnel	Lake, Colo	Day Mines, Inc	Silver ore.
10	Bunker Hill	Shoshone, Idaho	The Bunker Hill Co	Lead-zinc ore.
11	Sierrita	Pima, Ariz	Duval Sierrita Corp	Copper ore.
12	Twin Buttes	do	Anamax Mining Co	Do.
13	Buick	Iron, Mo	Amax Lead Co. of Missouri	Lead ore.
14	Star Unit	Shoshone, Idaho	Hecla Mining Co	Lead, lead-zinc ores.
15	Tyrone	Grant, N. Mex	Phelps Dodge Corp	Copper ore.
16	Morenci	Greenlee, Ariz	do	Do.
17	Magma	Pinal, Ariz	Magma Copper Co	Do.
18	Crescent	Shoshone, Idaho	The Bunker Hill Co	Silver ore.
19	Black Pine	Granite, Mont	Black Pine Mining Co	Do.
20	San Manuel	Pinal, Ariz	Magma Copper Co	Copper ore.
21	Mission Unit	Pima, Ariz	ASARCO Incorported	Do.
22	Trixie	Utah, Utah	Kennecott Copper Corp	Gold-silver ore.
23	Bagdad	Yavapai, Ariz	Cyprus Bagdad Copper Co	Copper ore.
24	Magmont	Iron, Mo	Cominco American, Inc	Lead ore.
25	Metcalf	Greenlee, Ariz	Phelps Dodge Corp	Copper ore.

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[36] Lucio, F. de, and M. Vargas. Silver Recovery Increased From 70 to 86 Percent. World Min., v.32, No. 6, June 1979, pp. 60-61.

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Table 4.—Twenty-five leading silver-producing mines in the United States in 1979, in order of output

Rank	Mine	County and State	Operator	Source of silver
1	Galena	Shoshone, Idaho	ASARCO Incorporated	Silver ore.
2	Sunshine	do	Sunshine Mining Co	Do.
3	Lucky Friday	do	Hecla Mining Co	Do.
4	Berkeley Pit	Silver Bow, Mont	The Anaconda Company	Copper ore.
5	Coeur	Shoshone, Idaho	ASARCO Incorporated	Silver ore.
6	Utah Copper	Salt Lake, Utah	Kennecott Copper Corp	Copper ore.
7	Twin Buttes & Palo Verde	Pima, Ariz	Anamax Mining Co	Do.
8	DeLamar	Owyhee, Idaho	Earth Resources Co	Gold-silver ore.
9	Bulldog Mountain	Mineral, Colo	Homestake Mining Co	Silver ore, silver tailings.
10	Sierrita	Pima, Ariz	Duval Corp	Copper ore.
11	Buick	Iron, Mo	Amax Lead Co. of Missouri	Lead ore.
12	Sherman Tunnel	Lake, Colo	Day Mines, Inc	Silver ore.
13	Tyrone	Grant, N. Mex	Phelps Dodge Corp	Copper ore.
14	Bunker Hill	Shoshone, Idaho	The Bunker Hill Co	Lead-zinc ore.
15	Star Unit	do	Helca Mining Co	Do.
16	Crescent	do	The Bunker Hill Co	Silver ore.
17	Morenci	Greenlee, Ariz	Phelps Dodge Corp	Copper ore.
18	Magma	Pinal, Ariz	Magma Copper Co	Do.
19	San Manuel	do	do	Do.
20	Black Pine	Granite, Mont	Black Pine Mining Co	Silver ore.
21	White Pine	Ontonagon, Mich	White Pine Copper Div	Copper ore.
22	Bagdad	Yavapai, Ariz	Cyprus Bagdad Copper Co	Do.
23	Gooseberry	Storey, Nev	West Coast Oil & Gas Corp	Gold ore.
24	Mission Unit	Pima, Ariz	ASARCO Incorporated	Copper ore.
25	Magmont	Iron, Mo	Cominco American, Inc	Lead ore.

Table 5.—Silver produced in the United States, in 1978, by State, type of mine, and class of ore, yielding silver, in terms of recoverable metal

State	Placer (troy ounces of silver)	Lode					
		Gold ore		Gold-silver ore		Silver ore	
		Short tons	Troy ounces of silver	Short tons	Troy ounces of silver	Short tons	Troy ounces of silver
Alaska	1,831	35	2	4	61	--	--
Arizona	--	--	--	--	--	W	W
California	178	15,319	2,345	W	W	--	--
Colorado	--	W	W	5,982	19,709	217,129	3,425,209
Idaho	--	82	71	W	W	794,486	14,391,007
Missouri	--	--	--	--	--	--	--
Montana	W	41,191	640	5,636	48,083	80,989	587,726
Nevada	W	1,799,866	432,346	14	220	1,113	11,548
New Mexico	--	W	W	10,282	61,440	59	266
New York	--	--	--	--	--	--	--
Oregon	--	2,455	1,714	--	--	--	--
South Dakota	--	1,590,406	53,099	--	--	--	--
Other States[1]	10	49,761	65,646	715,684	2,485,165	8,400	38,080
Total	2,014	3,499,115	555,863	737,602	2,614,678	1,102,176	18,453,836
Percent of total silver	(2)	--	1	--	7	--	47

State	Lode					
	Copper ore		Lead ore		Zinc ore	
	Short tons	Troy ounces of silver	Short tons	Troy ounces of silver	Short tons	Troy ounces of silver
Alaska	4	15	--	--	--	--
Arizona	164,474,460	6,611,722	W	W	--	--
California	--	--	--	--	--	--
Colorado	--	--	40	62	--	--
Idaho	W	W	57	3,072	3,000	266
Missouri	--	--	8,776,769	2,056,053	--	--
Montana	17,889,635	2,281,180	--	--	--	--
Nevada	W	W	--	--	--	--
New Mexico	W	W	--	--	W	W
New York	--	--	--	--	376,839	20,911
Oregon	--	--	--	--	--	--
South Dakota	--	--	--	--	--	--
Other States[1]	63,662,081	3,563,209	1,825	2,823	1,006,305	50,132
Total	246,026,180	12,456,126	8,778,191	2,062,010	1,386,144	71,309
Percent of total silver	--	32	--	5	--	(2)

State	Lode				Total[3]	
	Copper-lead, lead-zinc, copper-zinc, and copper-lead-zinc ores		Old tailings, etc.			
	Short tons	Troy ounces of silver	Short tons	Troy ounces of silver	Short tons	Troy ounces of silver
Alaska	--	--	14	143	57	2,052
Arizona	--	--	46,402	15,888	164,524,652	6,637,838
California	--	--	W	W	17,061	58,014
Colorado	510,977	581,808	W	W	809,286	4,217,181
Idaho	870,030	2,021,775	--	--	2,393,719	18,379,417
Missouri	--	--	--	--	8,776,769	2,056,053
Montana	W	W	--	--	18,017,516	2,918,317
Nevada	W	W	--	--	4,373,684	803,887
New Mexico	--	--	--	--	21,892,635	894,833
New York	--	--	--	--	376,839	20,911
Oregon	--	--	--	--	2,455	1,714
South Dakota	--	--	--	--	1,590,406	53,099
Other States[1]	2,216,161	322,392	75,155	[4]227,528	42,473,068	3,342,054
Total	3,597,168	2,925,975	121,571	243,559	265,248,147	39,385,870
Percent of total silver	--	7	--	1	--	100

W Withheld to avoid disclosing company proprietary data; included in "Other States."

[1] Includes Illinois, Michigan, Tennessee, Texas, Utah, Washington, and States indicated by symbol W.

[2] Less than 1/2 unit.

[3] Data may not add to State totals because of items withheld to avoid disclosing company proprietary data.

[4] Includes byproduct silver recovered from tungsten ore in California and fluorspar in Illinois.

Table 6.—Silver produced in the United States, in 1979, by State, type of mine, and class of ore, in terms of recoverable metal

State	Placer (troy ounces of silver)	Lode					
		Gold ore		Gold-silver ore		Silver ore	
		Short tons	Troy ounces of silver	Short tons	Troy ounces of silver	Short tons	Troy ounces of silver
Arizona	--	80,521	1,839	--	--	7,016	3,361
Colorado	--	--	--	6,411	25,269	204,788	2,512,280
Idaho	--	120	6	W	W	775,328	13,681,900
Missouri	--	--	--	--	--	--	--
Montana	--	262	153	3,633	12,841	78,057	567,405
Nevada	--	1,679,443	516,517	W	W	402	2,041
New Mexico	--	1,730	4,531	13,486	59,409	--	--
New York	--	--	--	--	--	--	--
Oregon	--	1,675	1,572	--	--	--	--
South Dakota	--	1,429,886	57,973	--	--	--	--
Other States[1]	431	53,326	57,391	732,691	2,055,326	--	--
Total	431	3,246,963	639,982	756,221	2,152,845	1,065,591	16,766,967
Percent of total silver	(2)	--	2	--	6	--	44

State	Lode					
	Copper ore		Lead ore		Zinc ore	
	Short tons	Troy ounces of silver	Short tons	Troy ounces of silver	Short tons	Troy ounces of silver
Arizona	181,506,717	7,451,824	562	2,482	--	--
Colorado	--	--	9	246	--	--
Idaho	W	W	727	10,244	--	--
Missouri	--	--	9,108,388	2,201,112	--	--
Montana	17,122,259	2,657,847	12,884	61,719	--	--
Nevada	W	W	--	--	--	--
New Mexico	27,122,254	1,285,572	192	249	--	--
New York	--	--	--	--	126,744	10,538
Oregon	--	--	--	--	--	--
South Dakota	--	--	--	--	--	--
Other States[1]	41,601,347	2,679,820	50	2,551	545,548	2,446
Total	267,352,577	14,075,063	9,122,812	2,278,603	672,292	12,984
Percent of total silver	--	37	--	6	--	(2)

State	Lode				Total[3]	
	Copper-lead, lead-zinc, copper-zinc, and copper-lead-zinc ores		Old tailings, etc.			
	Short tons	Troy ounces of silver	Short tons	Troy ounces of silver	Short tons	Troy ounces of silver
Arizona	--	--	37,491	19,436	181,632,307	7,478,942
Colorado	180,236	271,153	6	6	391,450	2,808,934
Idaho	827,835	1,664,586	--	--	2,338,456	17,144,209
Missouri	--	--	--	--	9,108,388	2,201,112
Montana	188	1,896	5	67	17,217,288	3,301,928
Nevada	--	--	--	--	1,719,136	528,588
New Mexico	--	--	--	--	27,137,662	1,349,761
New York	--	--	--	--	126,744	10,538
Oregon	--	--	--	--	1,675	1,572
South Dakota	--	--	--	--	1,429,886	57,973
Other States[1]	2,095,410	117,926	4,991	[4]53,274	44,259,626	3,171,662
Total	3,103,669	2,055,561	42,493	72,783	285,362,618	38,055,219
Percent of total silver	--	5	--	(2)	--	100

W Withheld to avoid disclosing company proprietary data. Included in "Other States."

[1] Includes Alaska, California, Illinois, Michigan, Tennessee, Utah, Washington, and States indicated by symbol W.

[2] Less than 1/2 unit.

[3] Data may not add to State totals because of items withheld to avoid disclosing company proprietary data.

[4] Includes byproduct silver recovered from tungsten ore in California and fluorspar in Illinois.

Table 7.—Mine production of recoverable silver in the United States, by State

(Troy ounces)

	1975	1976	1977	1978	1979
Alaska	W	3,265	1,725	2,052	W
Arizona	6,285,854	7,615,112	6,828,145	6,637,838	7,478,942
California	79,757	57,265	57,891	58,014	64,185
Colorado	3,366,000	4,083,171	4,663,496	4,217,181	2,808,934
Idaho	13,868,133	11,561,421	15,291,964	18,379,417	17,144,209
Michigan	632,336	310,837	335,479	W	W
Missouri	2,525,042	2,277,013	2,362,752	2,056,053	2,201,112
Montana	2,616,626	3,278,629	3,367,442	2,918,317	3,301,928
Nevada	1,608,735	783,892	738,402	803,887	528,588
New Mexico	792,050	891,932	918,155	894,833	1,349,761
New York	56,047	49,199	56,353	20,911	10,538
Oregon	W	--	7,134	1,714	1,572
South Dakota	67,669	58,117	68,717	53,099	57,973
Tennessee	53,752	77,890	60,246	W	W
Utah	2,821,730	3,134,021	3,283,323	2,885,065	2,454,136
Washington	W	W	120,582	W	W
Other States	163,851	146,466	3,897	456,989	653,341
Total	34,937,582	34,328,230	38,165,703	39,385,370	38,055,219

W Withheld to avoid disclosing company proprietary data; included in "Other States."

Table 8.—Silver produced in the United States from ore, old tailings, etc., in 1978-79, by State and method of recovery, in terms of recoverable metal

State	Total ore, old tailings, etc. treated[1] [2] (thousand short tons)	Ore and old tailings to mills					Crude ore, old tailings, etc., to smelters[1]	
		Thousand short tons[1] [2]	Recoverable in bullion		Concentrates smelted and recoverable metal			
			Amalgamation (troy ounces)	Cyanidation (troy ounces)	Concentrates (short tons)	Troy ounces	Thousand short tons	Troy ounces
1978:								
Alaska	(3)	(3)	--	--	1	2	(3)	219
Arizona	178,895	178,000	--	--	3,112,494	6,610,226	895	27,612
California	17	17	316	2	3,095	53,211	(3)	4,312
Colorado	809	800	333	190,376	81,450	3,822,377	9	204,095
Idaho	2,394	2,393	5	1,923,779	153,166	16,442,762	1	12,871
Missouri	8,777	8,777	--	--	849,761	2,056,053	--	--
Montana	[4]18,022	[4]17,932	--	806	333,047	2,298,719	90	618,785
Nevada	[4]7,117	[4]7,083	--	432,295	75,422	368,923	34	2,666
New Mexico	21,920	21,818	--	--	660,674	806,241	102	88,592
New York	433	433	--	--	54,840	20,911	--	--
Oregon	2	(3)	--	--	--	--	2	1,714
South Dakota	1,590	1,590	--	53,099	--	--	--	--
Utah	36,147	36,046	--	--	744,360	2,345,226	101	539,839
Washington	227	227	--	--	8,698	51,592	(3)	3,938
Other States[5]	8,795	8,795	--	--	395,700	401,459	--	--
Total	285,145	283,911	654	2,600,357	6,472,708	35,277,702	1,234	1,504,643
1979:								
Arizona	[4]204,463	[4]203,902	30	1,809	3,481,562	7,435,053	561	42,050
Colorado	453	442	--	--	39,554	2,529,614	11	279,320
Idaho	2,339	2,335	--	1,762,282	149,062	15,338,766	4	43,161
Missouri	9,108	9,108	--	--	875,482	2,201,112	--	--
Montana	17,280	17,135	--	1	306,115	2,700,624	95	601,303
Nevada	[4]4,563	[4]4,563	--	514,865	937	9,683	(3)	4,040
New Mexico	27,161	27,062	--	--	920,305	1,284,500	99	65,261
New York	159	159	--	--	25,152	10,538	--	--
Oregon	2	--	--	--	--	--	2	1,572
South Dakota	1,430	1,430	--	57,973	--	--	--	--
Utah	37,905	37,859	--	--	83,826	2,165,575	46	288,561
Other States[6]	9,399	9,398	140	--	400,929	706,307	1	10,648
Total	314,212	313,393	170	2,336,930	6,282,924	34,381,772	819	1,335,916

[1] Includes some non-silver-bearing ore not separable.
[2] Excludes tonnages of fluorspar and tungsten ores from which silver was recovered as a byproduct.
[3] Less than 1/2 unit.
[4] Includes ore from which silver was recovered by heap leaching.
[5] Includes Illinois, Michigan, Tennessee, and Texas.
[6] Includes California, Illinois, Michigan, Tennessee, and Washington.

Table 9.—Silver produced at amalgamation and cyanidation mills in the United States and percentage of silver recoverable from all sources

Year	Bullion and precipitates recoverable (troy ounces)		Silver recoverable from all sources (percent)			
	Amalgamation	Cyanidation	Amalgamation	Cyanidation	Smelting[1]	Placers
1975	2,293	420,077	0.01	1.20	98.79	(2)
1976	1,862	407,375	(2)	1.19	98.80	0.01
1977	16,720	1,308,209	.04	3.43	96.52	.01
1978	654	2,600,357	(2)	6.60	93.39	.01
1979	170	2,336,930	(2)	6.14	93.86	(2)

[1] Crude ores and concentrates.
[2] Less than 0.005%.

Table 10.—Silver produced at refineries in the United States, by source

(Thousand troy ounces)

Source	1978	1979
Concentrates and ores:		
Domestic	44,018	38,982
Foreign	10,342	11,779
Total	54,360	50,761
Old scrap:		
Coins	1,331	3,909
Other	35,751	34,110
Total	37,082	38,019
Total net production	91,442	88,780
New scrap	41,171	39,424
Grand total	132,613	128,204

Table 11.—U.S. consumption of silver, by end use

(Thousand troy ounces)

Final use[1]	1978	1979
Electroplated ware	7,274	8,065
Sterlingware	17,908	13,088
Jewelry	6,766	5,358
Photographic materials	64,299	65,978
Dental and medical supplies	2,033	2,295
Mirrors	1,862	1,850
Brazing alloys and solders	10,987	10,912
Electrical and electronic products:		
Batteries	6,029	4,583
Contacts and conductors	30,756	33,566
Bearings	373	332
Catalysts	8,197	5,637
Coins, medallions, commemorative objects	2,727	4,676
Miscellaneous[2]	954	978
Total net industrial consumption	160,165	157,258
Coinage	45	168
Total consumption	160,210	157,426

[1] End use as reported by converters of refined silver.
[2] Includes silver-bearing copper, silver-bearing lead anodes, ceramics, paints, etc.

Table 12.—Value of silver exported from and imported into the United States

(Thousand dollars)

Year	Exports	Imports
1977	84,645	355,953
1978	119,125	389,016
1979	471,162	961,761

Table 13.—U.S. exports of silver in 1978-79, by country

Destination	Ore and concentrates		Waste and sweepings		Doré and precipitates		Refined bullion		Total	
	Thousand troy ounces	Value (thousands)	Thousand troy ounces	Value (thousands)	Thousand troy ounces	Value (thousands)	Thousand troy ounces	Value (thousands)	Thousand troy ounces	Value (thousands)
1978										
Argentina	--	--	--	--	5	$28	120	$674	125	$702
Austria	--	--	--	--	--	--	490	2,750	490	2,750
Belgium-Luxembourg	--	--	1,835	$9,114	1,095	5,471	2	10	2,932	14,595
Canada	34	$131	897	4,557	161	813	121	629	1,213	6,130
France	--	--	42	86	--	--	--	--	42	86
Germany, Federal Republic of	--	--	280	1,087	206	1,136	21	105	507	2,328
Italy	--	--	--	--	--	--	32	168	32	168
Japan	--	--	2,818	14,486	226	1,828	4,680	25,177	7,724	41,491
Korea, Republic of	--	--	18	94	--	--	72	432	90	526
Netherlands	--	--	--	--	--	--	2,026	11,448	2,026	11,448
Spain	--	--	395	2,120	--	--	--	--	395	2,120
Sweden	--	--	268	1,193	--	--	--	--	268	1,193
Switzerland	--	--	319	1,707	--	--	1	5	320	1,712
Taiwan	--	--	(¹)	1	37	331	4	18	41	350
United Kingdom	--	--	2,951	15,733	810	4,560	2,418	13,162	6,179	33,456
Other	(¹)	1	6	17	7	38	3	17	16	73
Total²	34	132	9,830	50,194	2,547	14,205	9,989	54,594	22,400	119,125
1979										
Belgium-Luxembourg	4	39	5,031	78,126	399	5,561	923	15,747	6,357	99,473
Canada	16	65	2,571	30,221	31	336	87	1,287	2,705	31,909
France	2	16	125	2,161	(¹)	2	87	1,590	214	3,769
Germany, Federal Republic of	--	--	657	8,610	85	880	--	--	742	9,490
Japan	4	40	2,088	16,122	286	4,367	4,745	47,389	7,123	67,918
Korea, Republic of	--	--	--	--	--	--	78	513	78	513
Panama	--	--	--	--	--	--	33	271	33	271
Spain	--	--	207	3,510	--	--	--	--	207	3,510
Sweden	--	--	154	1,811	--	--	--	--	154	1,811
Switzerland	--	--	4	35	--	--	10,107	108,772	10,111	108,807

Taiwan	1	1	--	--	34	421	46	433	81	855
United Kingdom	13	52	6,134	71,635	1,371	9,493	219	1,406	7,737	82,646
Other	3	23	10	93	--	--	7	73	20	189
Total[2]	44	227	16,981	212,323	2,206	21,060	16,332	237,542	35,563	471,162

[1] Less than 1/2 unit.

[2] Data may not add to totals shown because of independent rounding.

Table 14.—U.S. imports for consumption of silver in 1978-79, by country

Country	Ore and concentrates		Waste and sweepings		Doré and precipitates		Refined bullion		Total	
	Thousand troy ounces	Value (thousands)	Thousand troy ounces	Value (thousands)	Thousand troy ounces	Value (thousands)	Thousand troy ounces	Value (thousands)	Thousand troy ounces	Value (thousands)
1978:										
Argentina	87	$540	--	--	64	$307	80	$385	231	$1,232
Bolivia	86	146	--	--	--	--	--	--	86	146
Brazil	87	377	--	--	--	--	--	--	87	377
Canada	1,045	3,600	1,420	$6,468	1,416	6,404	30,460	163,181	34,341	179,658
Chile	404	1,907	--	--	32	161	273	1,451	709	3,519
Colombia	27	152	--	--	--	--	--	--	27	152
Dominican Republic	--	--	--	--	--	--	107	600	107	600
Germany, Federal Republic of	49	256	--	--	(1)	1	--	--	49	257
Honduras	1,592	7,386	--	--	--	--	33	104	1,625	7,490
Hong Kong	--	--	17	89	6	33	12	67	35	189
Japan	36	148	--	--	96	465	942	4,900	1,074	5,513
Mexico	1,895	8,508	95	363	392	1,943	16,116	83,045	18,498	93,859
Nicaragua	25	125	--	--	14	72	398	1,988	437	2,185
Panama	--	--	(1)	2	17	145	(1)	3	17	150
Peru	4,316	22,362	--	--	978	3,287	11,490	59,746	16,784	85,395
Singapore	--	--	15	69	--	--	--	--	15	69
United Kingdom	4	6	35	176	1	4	(1)	3	40	189
Yugoslavia	--	--	--	--	--	--	1,435	7,872	1,435	7,872
Other	8	21	21	85	(1)	2	11	59	40	167
Total[2]	9,662	45,535	1,605	7,258	3,015	12,824	61,359	323,404	75,641	389,016
1979:										
Argentina	55	467	--	--	--	--	--	--	55	467
Australia	60	385	(1)	1	1	4	46	701	107	1,091
Belgium-Luxembourg	--	--	410	4,000	--	--	490	3,643	900	7,643
Bolivia	65	227	--	--	--	--	--	--	65	227
Brazil	159	1,304	267	2,756	32	332	45	465	503	4,857
Canada	1,135	6,714	600	5,150	202	1,317	24,774	264,025	26,711	277,206
Chile	363	2,865	--	--	1,015	8,866	820	10,086	2,198	21,817
Colombia	44	494	--	--	--	--	--	--	44	494
Dominican Republic	--	--	(1)	2	--	--	161	1,211	161	1,213
Germany, Federal Republic of	8	77	7	63	(1)	2	1	7	16	149
Honduras	1,386	13,923	(1)	2	--	--	7	44	1,393	13,969
Japan	--	--	--	--	17	268	834	10,913	851	11,181

Malaysia	--	--	22	208	--	--	--	--	22	203
Mexico	880	8,637	72	480	428	3,807	24,100	244,064	25,480	256,988
Netherlands	--	--	--	--	--	--	1,315	20,956	1,315	20,956
Nicaragua	13	108	--	--	12	73	263	1,625	288	1,806
Panama	--	--	17	150	18	117	2	15	37	282
Paraguay	--	--	44	458	--	--	127	2,268	171	2,726
Peru	5,684	47,040	--	--	785	8,712	13,411	182,697	19,880	188,449
Philippines	65	979	13	110	--	--	--	--	78	1,089
Singapore	--	--	18	227	--	--	--	--	18	227
U.S.S.R	--	--	--	--	--	--	129	2,093	129	2,093
United Kingdom	2	11	5	28	(1)	3	10,584	131,192	10,591	131,234
Yugoslavia	--	--	--	--	64	382	1,251	14,540	1,315	14,922
Other	10	34	28	220	3	32	13	184	54	470
Total[2]	9,928	83,266	1,504	13,849	2,577	23,915	76,372	840,731	92,381	961,761

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[1] Less than 1/2 unit.

[2] Data may not add to totals shown because of independent rounding.

Table 15.—Silver: World production,[1] by country

(Thousand troy ounces)

Country[2]	1976	1977	1978[p]	1979[e]
North and Central America:				
Canada	41,199	42,236	40,733	[3]38,068
Costa Rica[e]	2	1	2	2
Dominican Republic	907	1,357	1,848	1,900
El Salvador	166	112	185	200
Guatemala	NA	NA	10	10
Honduras	[r]3,184	2,819	2,788	3,000
Mexico	42,640	47,030	50,779	[3]49,310
Nicaragua	[r]208	153	482	300
United States	34,328	38,166	39,385	[3]38,055
South America:				
Argentina	[r]2,250	2,451	[e]2,600	2,600
Bolivia	5,091	6,254	6,439	[3]5,742
Brazil[4]	[r][6]438	372	[e]506	510
Chile	[r]7,342	8,461	8,210	8,322
Colombia[5]	[r]107	91	83	100
Ecuador	[r]47	57	64	70
Peru	35,579	39,088	37,045	43,415
Europe:				
Bulgaria[e]	900	840	900	920
Czechoslovakia[e]	1,190	1,192	1,300	1,300
Finland	773	813	1,183	[3]1,028
France	2,806	3,004	2,754	[3]2,409
German Democratic Republic[e]	1,600	1,600	1,600	1,600
Germany, Federal Republic of	1,026	1,061	799	800
Greece[e]	[r]1,845	1,070	1,360	1,400
Greenland	[r]479	521	559	[3]617
Hungary[e]	32	39	39	39
Ireland	925	936	631	600
Italy[5] [7]	[r]1,593	1,222	890	[3]1,065
Poland[e]	[r]17,800	[r]20,708	21,900	23,000
Portugal	[r]28	26	23	[3]31
Romania[e]	[r]1,220	[r]1,125	1,030	1,030
Spain	[r]3,222	3,215	3,092	3,000
Sweden	4,617	5,438	5,144	5,000
U.S.S.R.[e] [5]	44,000	45,000	46,000	46,000
Yugoslavia[5]	4,631	4,679	5,112	[3]5,208
Africa:				
Algeria[e]	[r]80	[r]40	75	100
Ghana	NA	NA	19	20
Kenya	(8)	--	--	--
Mauritania	32	[e]26	19	--
Morocco	2,054	2,244	2,315	2,418
Rhodesia, Southern (Zimbabwe)	200	207	1,109	977
South Africa, Republic of	2,821	3,130	3,104	[3]3,236
South-West Africa, Territory of (Namibia)	1,400	1,684	1,399	[3]1,606
Tanzania	(8)	--	--	--
Tunisia	[r]257	236	231	231
Zaire	2,472	2,730	4,391	2,500
Zambia	1,065	[r][e]1,450	1,069	1,000
Asia:				
Burma	[r]211	355	377	272
China:				
Mainland[e]	[r]1,000	[r]1,000	1,500	2,000
Taiwan	100	68	75	75
India[5]	102	425	389	450
Indonesia	[r]1,072	790	826	850
Japan	9,299	9,646	9,645	8,665
Korea, North[e]	1,600	1,600	1,600	1,600
Korea, Republic of	[r]1,856	2,104	2,066	[3]2,819
Malaysia (Sabah)	[e]300	[e]430	482	450
Philippines	1,481	1,621	1,668	[3]91,824
Turkey	[e]220	[e]220	219	250
Oceania:				
Australia	[r]25,034	27,525	24,934	25,000
Fiji	20	15	10	11
New Zealand	1	8	2	2
Papua New Guinea	[r]1,451	1,522	1,706	1,450
Total	[r]316,303	[r]340,213	344,657	344,457

[e]Estimate. [p]Preliminary. [r]Revised. NA Not available.

[1] Recoverable content of ores and concentrates produced unless otherwise noted.

[2] In addition to the countries listed, Austria and Thailand may produce silver, but information is inadequate to make reliable estimates of output levels.

[3] Reported figure.

[4] Includes 20,126 ounces of silver recovered from gold ore plus an estimated 418,000 ounces of silver recovered as a byproduct from lead in 1976; includes 14,239 ounces of silver recovered from gold ore plus 358,062 ounces of silver recovered as a byproduct from lead in 1977; 1978—NA.

[5] Smelter and/or refinery production.

[6] Series changed to show mine production.

[7] Includes production from imported ores.

[8] Less than 1/2 unit.

Slag-Iron and Steel

Alvin B. Zlobik[1]

Combined sales and usage of iron and steel slag in 1978 and 1979 totaled 36.9 million tons[2] and 35.8 million tons, respectively. Iron slags totaled 28.4 million tons in 1978 and 27.5 million tons in 1979; steel slag totaled 8.5 million tons and 8.3 million tons in these respective years. Total sales value for 1978, $101 million, was 23% higher than in 1977 and increased further to $111 million in 1979. Average value per ton of iron slag was $3.04 in 1978 and increased 10% to $3.35 in 1979. Average value per ton of steel slag increased 30% to $2.24 in 1979.

DOMESTIC PRODUCTION

Iron slags sold or used in 1978 increased 10% in tonnage to 28.4 million tons and 21% in value to $86.4 million. Sales/use of expanded iron slag increased significantly, 30% in quantity and 50% in value over that in 1977. Sales of iron slag in 1979 decreased 3% in quantity but increased 7% in value from that in 1978. The average value per ton of all iron slags in 1978 was $3.04 while the average value in 1979 was $3.35.

Steel slags sold or used in 1978 and 1979 totaled 8.5 million tons and 8.3 million tons and had values of $14.5 million and $18.5 million, respectively.

Pennsylvania, Ohio, and Indiana, in that order, were the leading producing States during the 1978-79 period. Steel slags were processed at 39 operations in 15 States during 1979.

In 1978, approximately 75% of iron and steel slag products in the United States were shipped to market by truck; 82% were shipped by truck in 1979. Rail and waterway shipments averaged 12% and 4%, respectively, during the 1978-79 period. The remaining material was used onsite.

CONSUMPTION AND USES

There were no known imports or exports of iron or steel slags in the 1978-79 period. As usual, most domestic slags were consumed in the construction industry.

Most salable iron slag banks in the United States have been exhausted, and the availability of iron slag is largely dependent on newly produced blast-furnace iron from iron and steel plants. An undetermined tonnage of steel slag banks exists. Before it can be utilized, some steel slag requires a natural aging process in order to minimize expansion, due to the hydration of free lime, during end use. Some iron and steel slags are high in metallic iron content and unsuitable for sale to the construction industry; however, these high iron slags can be recycled to the blast furnaces.

Air-cooled iron blast-furnace slag continued to be the most important slag product in terms of both tons processed and in the number of different types of use. Locally, iron slag is competitive with sand and gravel and crushed stone, principally for use as aggregate. Air-cooled iron slag shows excellent bonding characteristics when mixed with portland cement to make concrete. It also shows high stability when used in asphaltic concretes and high skid resistance when used in bituminous road surfacing.

Table 1.—Iron and steel slags sold or used in the United States, by type[1]

(Thousand short tons and thousand dollars)

Year	Iron blast-furnace slag								Steel slag		Total slag[2]	
	Air-cooled		Granulated		Expanded		Total iron slag[2]					
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1970	22,252	42,135	1,936	2,134	1,959	6,570	26,147	50,839	7,539	8,832	33,686	59,671
1971	21,444	42,352	1,787	2,445	1,581	4,887	24,812	49,684	8,488	9,719	33,300	59,403
1972	21,878	44,787	1,657	3,059	1,518	5,529	25,053	53,375	10,162	11,023	35,215	64,398
1973	24,971	52,249	1,999	3,667	1,852	6,936	28,822	62,852	9,739	10,765	38,561	73,617
1974	26,226	57,227	2,081	4,442	1,573	6,461	29,880	68,130	8,862	11,195	38,742	79,325
1975	22,242	53,386	1,780	4,335	1,302	5,934	25,324	63,655	7,302	8,965	32,626	72,620
1976	22,899	59,813	1,618	3,529	1,492	6,610	26,009	69,952	6,588	9,728	32,597	79,680
1977	22,753	61,270	1,488	3,579	1,475	6,414	25,716	71,262	6,668	10,850	32,384	82,112
1978	25,119	73,148	1,372	3,608	1,914	9,641	28,404	86,398	8,457	14,510	36,861	100,906
1979	25,009	78,415	855	3,037	1,648	10,794	27,512	92,246	8,252	18,476	35,764	110,722

[1] Value based on selling price at plant.
[2] Data may not add to totals shown because of independent rounding.

Source: National Slag Association (1970-76).

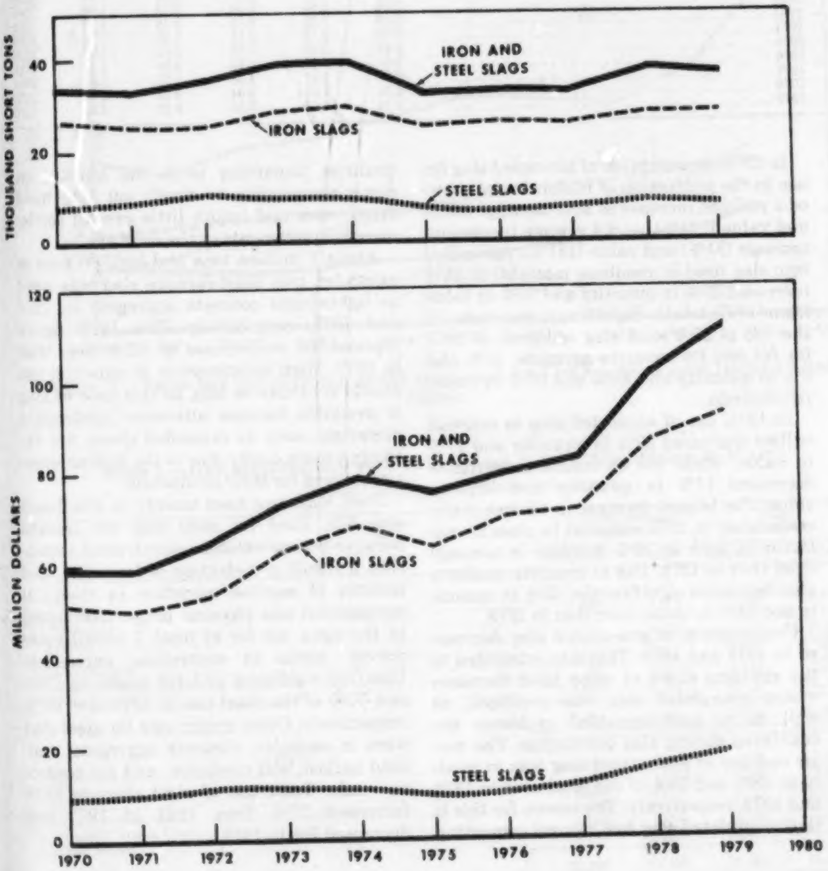


Figure 1.—Quantity and value (f.o.b. plant) of iron and steel slag sold or used in the United States.

Table 2.—Value per ton, at the plant, for iron and steel slags sold or used in the United States, by type

Year	Iron blast-furnace slag				Steel slag	Total slag
	Air-cooled	Granulated	Expanded	Total iron slag		
1970	$1.89	$1.10	$3.35	$1.94	$1.17	$1.77
1971	1.98	1.37	3.09	2.00	1.15	1.78
1972	2.05	1.85	3.64	2.13	1.08	1.83
1973	2.09	1.83	3.75	2.18	1.11	1.91
1974	2.18	2.13	4.11	2.28	1.26	2.05
1975	2.40	2.44	4.56	2.51	1.23	2.23
1976	2.61	2.18	4.43	2.69	1.48	2.44
1977	2.69	2.41	4.35	2.77	1.63	2.54
1978	2.91	2.63	5.04	3.04	1.72	2.74
1979	3.14	3.55	6.55	3.35	2.24	3.10

In 1978, consumption of air-cooled slag for use in the production of mineral wool showed a marked increase in both tonnage (88%) and value (133%), as did sewage treatment, tonnage (94%) and value (131%). Air-cooled iron slag used in roadbase material in 1978 increased 22% in quantity and 30% in value from 1977 totals. Significant increases in the use of air-cooled slag occurred in 1979 for fill and for concrete agregate, 44% and 8% in quantity and 81% and 26% in value, respectively.

In 1978, use of air-cooled slag in railroad ballast decreased 29% in quantity and 27% in value, while use as concrete aggregate decreased 14% in quantity and 13% in value. The largest decrease in the use of air-cooled slag in 1979 occurred in glass manufacturing with an 89% decrease in tonnage from that in 1978. Use in concrete products also decreased significantly, 45% in quantity and 34% in value from that in 1978.

Consumption of granulated slag decreased in 1978 and 1979. This was attributed to the shutting down of some blast furnaces where granulated slag was produced, as well as to environmental problems encountered during slag production. The major end use of granulated slag was in roadbase, 68% and 75% of the total used in 1978 and 1979, respectively. The reason for this is that granulated slag has natural cementing qualities imparting to it the ability, on damp compaction, to slowly set into hard dense mass and insure little overall settlement for pavements or the overlays.

About 1 million tons and 900,000 tons of expanded iron blast-furnace slag was used as lightweight concrete aggregate in 1978 and 1979, respectively. The 1978 figure represented an increase of 102% over that in 1977. High consumption in this end use should continue as long as this type of slag is available because alternate lightweight materials, such as expanded shale, are becoming more costly due to the higher energy required for their production.

Steel slags are used mainly in roadbases and fills. Uses for steel slag are limited because it may exhibit uncontrolled expansion, a result of hydration of free lime, and because of marked variation in chemical composition and physical properties. Aging in the open air for at least 3 months has proven useful in controlling expansion. Uses for roadbases and fill made up 78% and 74% of the total use in 1978 and 1979, respectively. Other major uses for steel slag were in asphaltic concrete aggregate, railroad ballast, soil condition, and ice control on roads. Total use of steel slags in 1978 increased 27% from that of 1977 but decreased 2% in 1979.

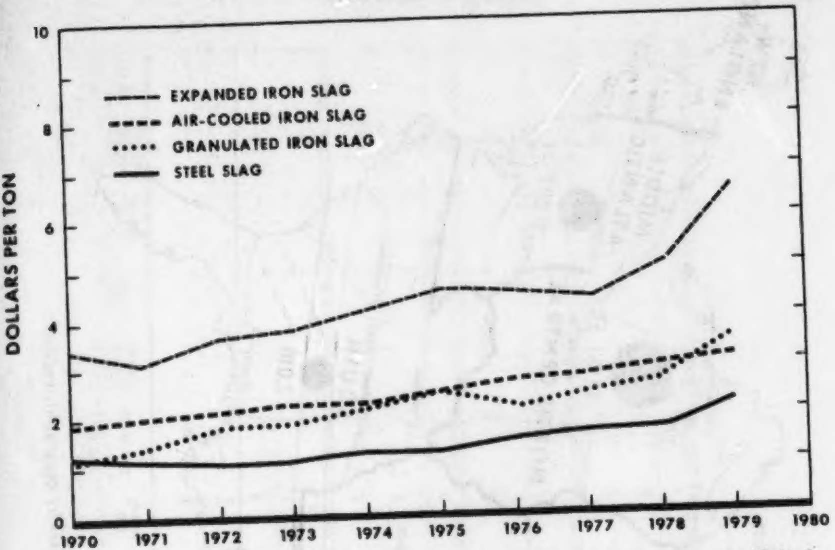


Figure 2.—Value per ton of iron slag (by type) and steel slag, sold or used in the United States.

Table 3.—Iron blast-furnace slags sold or used in the United States, by State[1]

(Thousand short tons and thousand dollars)

Year and State	Air-cooled, screened and unscreened		Total all types	
	Quantity	Value	Quantity	Value
1977				
Alabama	1,232	3,814	1,232	3,814
California	547	991	547	991
Illinois	1,131	3,128	1,131	3,128
Ohio	5,039	15,210	6,030	17,753
Pennsylvania	4,481	14,784	5,314	17,325
Colorado, Texas, Utah	1,707	3,877	1,707	3,877
Other States[2]	8,616	19,466	9,755	24,374
Total	22,753	61,270	25,716	71,262
1978				
California	648	1,328	648	1,328
Illinois	1,000	2,564	1,000	2,564
Ohio	4,451	16,217	5,340	18,997
Pennsylvania	5,686	19,619	6,670	23,213
Colorado, Texas, Utah	2,185	5,590	2,185	5,590
Other States[3]	11,149	27,831	12,561	34,706
Total[4]	25,119	73,148	28,404	86,398
1979				
California	663	1,482	663	1,482
Indiana	4,230	6,106	W	W
Kentucky	549	W	549	W
Ohio	4,448	17,580	5,157	W
Pennsylvania	5,518	20,424	6,042	24,390
Utah	1,028	2,273	1,028	2,273
West Virginia	843	W	843	W
Other[5]	7,729	30,551	13,230	64,101
Total[4]	25,009	78,415	27,512	92,246

W Withheld to avoid disclosing company proprietary data; included with "Other."

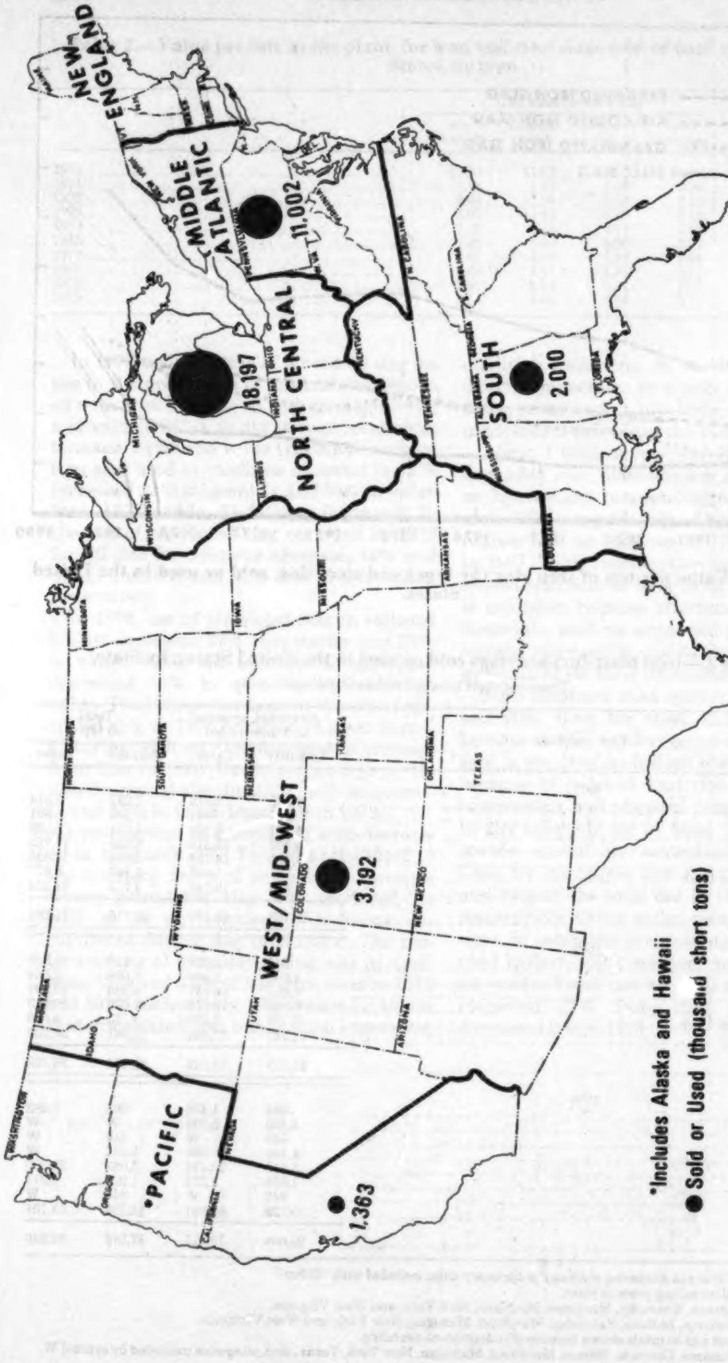
[1] Value based on selling price at plant.

[2] Includes Indiana, Kentucky, Maryland, Michigan, New York, and West Virginia.

[3] Includes Alabama, Indiana, Kentucky, Maryland, Michigan, New York, and West Viriginia.

[4] Data may not add to totals shown because of independent rounding.

[5] Includes Alabama, Colorado, Illinois, Maryland, Michigan, New York, Texas , and categories indicated by symbol W.


NEW ENGLAND
MIDDLE ATLANTIC
11,002
18,197
NORTH CENTRAL
SOUTH
2,010
WEST/MID-WEST
3,192
*PACIFIC
1,363

*Includes Alaska and Hawaii

● Sold or Used (thousand short tons)

Figure 3.—Iron and steel slag sold or used in the United States by geographic region.

Table 4.—Types and sources of iron and steel furnace slag processed in the United States[1]

State and City	Company	Iron slag			Steel slag	Source of steel slag		
		Air-cooled	Expanded	Granulated		Open hearth	Basic oxygen process	Electric
Alabama:								
Alabama City	Vulcan Materials Co	X	--	--	--	--	--	--
Ensley	Do	X	--	--	--	--	--	--
Fairfield	Do	X	--	--	--	--	--	--
Birmingham	U.S. Pipe and Foundry Co	X	X	--	--	--	--	--
Total		4	1	--	--	--	--	--
California: Fontana	Heckett Co	1	--	--	1	--	1	--
Colorado: Pueblo	Fountain Sand and Gravel Co	1	--	--	--	--	--	--
Delaware: Claymont	International Mill Service	--	--	--	1	--	--	1
Georgia: Atlanta	Do	--	--	--	1	--	--	1
Illinois:								
Chicago	Illinois Slag & Ballast Co	X	--	--	X	--	X	--
Do	Spang and Co	--	--	--	X	--	X	X
Granite City	International Mill Service	--	--	--	X	--	X	--
Do	St. Louis Slag Products, Co., Inc	X	--	--	--	--	--	--
Peoria	International Mill Service	--	--	--	X	--	--	X
Total		2	--	--	4	--	3	2
Indiana:								
Burns Harbor	The Levy Co	X	X	--	X	--	X	--
Gary	United States Steel Corp	X	X	--	--	--	--	--
East Chicago	Vulcan Materials Co	X	--	--	--	--	--	--
Total		3	2	--	1	--	1	--
Kentucky: Ashland	Standard Slag Co	1	--	--	--	--	--	--
Maryland:								
Baltimore	Maryland Slag Co	X	X	--	--	--	--	--
Easton	Do	S	S	--	--	--	--	--
Pocomoke City	Do	S	S	--	--	--	--	--
Salisbury	Do	S	S	--	--	--	--	--
Total		4	4	--	--	--	--	--

See footnotes at end of table.

Table 4.—Types and sources of iron and steel furnace slag processed in the United States[1]—Continued

State and City	Company	Iron slag			Steel slag	Source of steel slag		
		Air-cooled	Expanded	Granulated		Open hearth	Basic oxygen process	Electric
Michigan:								
Detroit	E. C. Levy Co	X	X	X	X	--	X	X
Ecorse	Do	--	--	--	X	--	X	X
Trenton	Do	X	--	--	X	--	X	--
Total		2	1	1	3	--	3	2
Minnesota: Newport	International Mill Service	--	--	--	1	--	--	1
New York:								
Buffalo	Buffalo Slag Co	X	X	--	--	--	--	--
Do	Heckett Co	--	--	--	X	--	X	--
Total		1	1	--	1	--	1	--
Ohio:								
Canton	Heckett Co	--	--	--	X	--	--	X
Cleveland	Stein, Inc	--	--	--	X	X	X	X
Do	Standard Slag Co	X	--	--	--	--	--	--
Do	Do	X	--	--	--	--	--	--
Hamilton	American Materials Corp	X	--	--	--	--	--	--
Lorain	Spang and Co	--	--	--	X	--	X	--
Do	United States Steel Corp	X	--	--	X	--	X	--
Lordstown	Standard Slag Co	X	--	X	X	X	--	--
Mansfield	International Mill Service	--	--	--	X	--	--	X
McDonald	United States Steel Corp	X	--	--	X	X	--	--
Middletown	American Materials Corp	X	--	--	--	--	--	--
Do	McGraw Construction Co	--	--	--	X	X	X	--
Mingo Junction	International Mill Service	--	--	--	X	--	X	--
Do	Standard Slag Co	X	--	--	--	--	--	--
New Boston	Do	X	X	--	--	--	--	--
Struthers	Do	--	--	X	--	--	--	--
Toledo	France Stone Co	X	--	--	--	--	--	--
Warren	Heckett Co	--	--	--	X	--	--	X
Do	Standard Slag Co	X	--	--	--	--	--	--
Youngstown	Do	X	--	--	--	--	--	--
Total		12	1	2	10	4	5	4
Oklahoma: Sand Springs	International Mill Service	--	--	--	1	--	--	1

Pennsylvania:								
Belle Vernon	Duquesne Slag Products Co	X	--	X	--	--	--	--
Bethlehem	Bethlehem Mines Corp	X	--	--	--	--	--	--
Do	Sheridan Slag Co	--	X	--	--	--	--	--
Birdsboro	Birdsboro Slag Products	X	--	--	--	--	--	--
Butler	Spang and Co	--	--	--	X	--	--	X
Coatesville	International Mill Service	--	--	--	X	--	--	X
Dunbar	Vanderbilt Slag Co	--	--	X	--	--	--	--
Lebanon	Sheridan Corp	X	--	--	--	--	--	--
McKees Rocks	Phillips Contracting	--	--	X	--	--	--	--
Midland	International Mill Service	X	--	--	X	--	--	X
Morrisville	Warner Co	X	X	--	--	--	--	--
Park Hill	Standard Slag Co	X	--	--	X	X	--	--
Penn Hills	United States Steel Corp	--	--	--	X	X	--	--
Phoenixville	International Mill Service	--	--	--	X	X	--	--
Pittsburgh	Duquesne Slag Products Co	X	--	--	--	--	--	--
Steelton	Hempt Bros	X	--	--	--	--	--	--
Swedeland	Sheridan Slag Corp	--	X	--	--	--	--	--
West Aliquippa	Duquesne Slag Products Co	X	--	--	X	--	X	--
West Mifflin	Do	X	--	--	X	X	X	--
Wheatland	Dunbar Slag Co	X	--	--	X	--	X	X
Total		12	3	3	9	4	3	4
South Carolina: Darlington	R.B. Ponds Construction Co	--	--	--	1	--	--	1
Texas:								
Beaumont	International Mill Service	--	--	--	X	--	--	X
Houston	Houston Slag Materials Co	X	--	--	X	--	--	X
Lone Star	Gifford-Hill Co	X	--	--	--	--	--	--
Midlothian	International Mill Service	--	--	--	X	--	--	X
Total		2	--	--	3	--	--	3
Utah: Provo	United States Steel Corp	1	--	--	1	1	--	--
Virginia: Virginia Beach	Maryland Slag Co	S	S	--	--	--	--	--
West Virginia:								
Weirton	International Mill Service	--	--	--	X	--	X	--
Do	Standard Slag Co	X	--	--	--	--	--	--
Total		1	--	--	1	--	1	--
Grand total		48	14	6	39	9	18	20

[1] X-represents method of steel processing; S-represents sources.

Table 5.—Shipments of iron and steel slag in the United States, by method of transportation

Method of transportation	1977		1978		1979	
	Quantity (thousand short tons)	Percent of total	Quantity (thousand short tons)	Percent of total	Quantity (thousand short tons)	Percent of total
Rail	4,105	13	4,913	13	3,832	11
Truck	26,047	80	27,437	75	29,519	82
Waterway	1,329	4	1,879	5	1,126	3
Not transported (used at plant site)	903	3	2,632	7	1,287	4
Total	32,384	100	36,861	100	35,764	100

Table 6.—Air-cooled iron blast-furnace slag sold or used in the United States, by use[1]

(Thousand short tons and thousand dollars)

Use	1977		1978		1979	
	Quantity	Value	Quantity	Value	Quantity	Value
Concrete aggregate	2,553	7,535	2,192	6,529	2,367	8,199
Concrete products	738	2,383	764	2,551	421	1,676
Cement manufacture	146	351	148	456	W	W
Asphaltic concrete aggregate	4,024	12,798	3,916	13,272	3,421	12,365
Roadbases	7,289	19,157	8,875	24,863	8,452	25,435
Fill	3,097	6,894	2,677	5,254	3,861	9,512
Railroad ballast	3,400	7,191	2,417	5,243	2,505	6,591
Mineral wool	525	1,457	987	3,390	826	3,374
Roofing, built-up and shingles	255	816	234	912	247	1,324
Sewage treatment	46	88	89	293	W	W
Soil conditioning	2	5	W	W	W	W
Glass manufacture	217	1,399	187	1,695	21	W
Ice control	27	76	W	W	W	W
Other uses[2]	433	1,119	2,632	8,779	2,889	9,939
Total[3]	22,753	61,270	25,119	73,148	25,009	78,415

W Withheld to avoid disclosing company proprietary data.

[1] Value based on selling price at plant.

[2] Includes airport runway base, drainage, miscellaneous, and uses indicated by symbol W.

[3] Data may not add to totals shown because of independent rounding.

Table 7.—Granulated and expanded iron blast-furnace slags sold or used in the United States, by use[1]

(Thousand short tons and thousand dollars)

Use	1977				1978				1979			
	Granulated		Expanded		Granulated		Expanded		Granulated		Expanded	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Lightweight concrete aggregate	--	--	509	2,265	--	--	1,030	5,799	83	W	931	6,388
Concrete products	119	447	916	4,047	107	W	652	3,089	--	--	607	3,865
Cement manufacture	60	211	50	101	W	W	78	457	W	W	W	W
Roadbases	1,064	2,264	--	--	936	2,201	--	--	637	W	--	--
Fill	151	404	--	--	214	578	W	W	W	W	W	W
Soil conditioning	45	115	--	--	48	W	--	--	25	--	--	--
Ice control	8	31	--	--	1	W	--	--	--	--	--	--
Other[2]	40	107	--	--	67	828	153	295	109	3,037	110	541
Total[3]	1,488	3,579	1,475	6,414	1,372	3,608	1,914	9,641	855	3,037	1,648	10,794

W Withheld to avoid disclosing company proprietary data.

[1] Value based on selling price at plant.

[2] Includes drainage, miscellaneous, and uses indicated by symbol W.

[3] Data may not add to totals shown because of independent rounding.

Table 8.—Steel slag sold or used in the United States, by use[1] [2]

(Thousand short tons and thousand dollars)

Use	1977 Quantity	1977 Value	1978 Quantity	1978 Value	1979 Quantity	1979 Value
Asphaltic concrete aggregate	396	776	607	1,264	822	2,481
Road bases	2,929	5,207	4,793	8,451	4,237	8,818
Fill	2,330	3,072	1,784	2,355	1,882	4,305
Railroad ballast	354	569	549	1,072	580	1,243
Soil conditioning	44	114	W	W	--	--
Fire protection	35	76	--	--	8	W
Other[3]	580	1,036	723	1,368	773	1,629
Total	6,668	10,850	[4]8,457	14,510	8,252	18,476

W Withheld to avoid disclosing company proprietary data; included in "Other."

[1] Excludes tonnage returned to furnace for charge material.

[2] Value based on selling price at plant.

[3] Includes ice control, miscellaneous, and uses indicated by symbol W.

[4] Data do not add up to total shown because of independent rounding.

PRICES

The weighted average selling prices and the range of selling prices of slag at the plant for all major uses are shown in table 9. The high prices in certain use categories indicate that some users demanded specifications which required more than normal processing.

Table 9.—Average selling price and range of selling prices at the plant for iron and steel slags in the United States, by use

(Dollars per short ton)

Use	Iron blast-furnace slag						Steel slag	
	Air-cooled		Granulated		Expanded			
	Average	Range	Average	Range	Average	Range	Average	Range
1978								
Concrete aggregate	2.98	.88- 4.28	--	--	--	--	--	--
Lightweight concrete aggregate	--	--	--	--	5.63	4.40-11.23	--	--
Concrete products	3.34	2.40- 4.05	W	W	4.74	3.00- 7.78	--	--
Cement manufacture	3.08	.58- 3.59	W	W	5.86	3.51-11.23	--	--
Asphaltic concrete aggregate	3.39	.91- 8.00	--	--	--	--	2.08	1.45-7.00
Roadbases	2.80	.79- 4.80	2.35	2.00-2.85	--	--	1.76	.67-5.00
Fill	1.96	.50- 4.04	2.70	1.65-4.17	W	W	1.32	.28-2.62
Railroad ballast	2.17	1.00- 4.50	--	--	--	--	1.95	1.25-4.50
Mineral wool	3.44	1.00- 5.32	--	--	--	--	--	--
Roofing, built-up and shingles	3.90	2.05- 5.10	--	--	--	--	--	--
Sewage treatment	2.28	2.05- 3.49	--	--	--	--	--	--
Soil conditioning	W	W	W	W	--	--	W	W
Glass manufacture	9.06	9.00-11.63	--	--	--	--	--	--
Ice control	W	W	W	W	--	--	W	W
Other	3.34	1.27- 4.04	3.71	2.96-5.50	1.93	1.50- 1.96	1.89	1.45- 3.30
1979								
Concrete aggregate	3.46	1.04- 7.05	--	--	--	--	--	--
Lightweight concrete aggregate	--	--	W	W	6.86	6.00-11.23	--	--
Concrete products	3.98	1.60- 7.58	--	--	6.37	4.50- 9.45	--	--
Cement manufacture	W	W	W	W	W	W	--	--
Asphaltic concrete aggregate	3.61	1.08- 6.00	--	--	--	--	3.02	1.65- 7.50
Roadbases	3.01	1.04- 4.85	W	W	--	--	2.08	.52- 5.25
Fill	2.46	.54- 5.30	W	W	W	W	2.29	.50- 5.00
Road ballast	2.63	1.06- 5.54	--	--	--	--	2.35	1.15- 5.00
Mineral wool	4.08	2.24- 7.20	--	--	--	--	--	--
Roofing, built-up and shingles	5.86	2.24-10.00	--	--	--	--	--	--
Sewage treatment	W	W	--	--	--	--	--	--
Soil conditioning	W	W	W	W	--	--	--	--

See footnotes at end of table.

Table 9.—Average selling price and range of selling prices at the plant for iron and steel slags in the United States, by use —Continued

(Dollars per short ton)

Use	Iron blast-furnace slag						Steel slag	
	Air-cooled		Granulated		Expanded			
	Average	Range	Average	Range	Average	Range	Average	Range
1979 —Continued								
Glass manufacture	W	W	--	--	--	--	--	--
Ice control	W	W	--	--	--	--	W	W
Other	3.42	.76-10.60	3.55	2.60-7.00	7.96	1.50-11.25	2.09	1.58-13.28

W Withheld to avoid disclosing company proprietary data; included with "Other."

WORLD REVIEW

Production of slag in other countries was not available for the 1978-79 period. Data pertaining to resources, amount available as newly made slag, and old stockpiles also were not available. However, resources and use are known to be significant in countries such as Japan, the Federal Republic of Germany, France and Great Britain where there is a large iron and steel industry.

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[1] Physical scientist, Section of Nonmetallic Minerals.

[2] Short tons are used throughout, unless otherwise stated.

Sodium and Sodium Compounds

By Dennis S. Kostick[1]

Production of natural soda ash increased substantially in 1979 in response to a shortage of the material caused by the closures of two Solvay plants in 1978. Although 1979 total soda ash production was down slightly compared with the previous year, exports increased 28% to an alltime high of over 997,000 short tons. Domestic demand, however, was down slightly, primarily in the glass industry. The greatest impact was on the flat glass sector of this industry due to smaller size and fewer automobiles being manufactured and a slowdown in construction starts. Total production of sodium sulfate in 1979 decreased 4%, while imports and exports increased. The industrial demand, however, continued to decline for the third consecutive year. Metallic sodium production increased about 9% from that of 1978. The quantity and value of sodium compounds produced in 1978 and 1979 follows:

	Production (thousand short tons)		Value (thousand dollars)	
	1978	1979	1978	1979
Natural soda ash	6,790	[1]8,253	371,255	476,711
Natural sodium sulfate	605	533	27,865	29,689
Metallic sodium	138	[p]151	93,494	[p]124,742

[p]Preliminary.

[1]Natural and synthetic combined to avoid disclosure of company proprietary data.

DOMESTIC PRODUCTION

The total domestic production of soda ash in 1979 was 8,252,794 short tons. Production of Solvay soda ash was combined with natural soda ash beginning in 1979 to avoid revealing company proprietary data. In 1978, production of 6,790,300 tons of natural soda ash was derived from trona or brine. This output was up 9% and represented 82% of the total amount of soda ash produced in the United States. Solvay soda ash declined by an estimated 17% and its continuing declining trend is illustrated in table 2.

PPG Industries, Inc., closed its Solvay plant on March 31, 1978, at Corpus Christi, Tex., due to rising costs of energy, raw materials, equipment maintenance, and compliance with antipollution regulations.[2] BASF Wyandotte Corp. also closed their Solvay facilities at yearend citing similar reasons. Combined capacity of these two plants was over 1 million tons of soda ash, which was more than half of the total 1977 domestic Solvay industry capacity. The sole remaining producer of Solvay soda ash is Allied Chemical Corp. with a plant located at Syracuse, N. Y.

Tenneco Oil Co. began construction of a new 1-million-ton-per-year-capacity trona mine and soda ash processing plant near Green River, Wyo.[3] The facility will use 350,000 tons of Wyoming coal per year as its main energy source; completion of construction should be in 1982. Kerr-McGee Chemical Corp. brought onstream 800,000 tons of additional capacity at its Argus, Calif., plant.[4] Final completion of the 1.3-million-ton-annual-capacity expansion was completed in early 1979, but startup problems have temporarily restricted total production. FMC Corp. announced it will utilize solution mining to obtain trona by 1983. This new technique is expected to add an additional 1 million tons of natural soda ash capacity to its present facility.[5] PQ Corp. is actively seeking partners to help develop its 183-million-ton reserve base of trona. The growing worldwide demand for soda ash is prompting several Wyoming leaseholders to examine their deposits.[6]

The total quantity of domestic sodium sulfate produced in 1979 was about 1.2 million tons. Natural sodium sulfate production declined 11% to 533,121 tons, or 45% of the total sulfate produced. Manufactured sodium sulfate production increased 3%. Kerr-McGee Chemical Corp. increased its natural sodium sulfate capacity at its Trona, Calif., plant by 150,000 tons annually.[7]

Metallic sodium production increased 9% to 151,459 tons. Table 4 illustrates the production and price trends since 1968. A list of U.S. producers of natural sodium compounds and metallic sodium follows:

Product and company	Plant location	Source of sodium
Soda ash:		
Kerr-McGee Chemical Corp	Trona, Calif	Dry lake brine.
Do	Argus, Calif.	Do.
Do	Westend, Calif	Do.
Allied Chemical Corp	Green River, Wyo	Underground trona.
FMC Corp	do	Do.
Stauffer Chemical Co. of Wyoming	do	Do.
Texasgulf Chemicals Co	Granger, Wyo	Do.
Sodium sulfate:		
Kerr-McGee Chemical Corp	Trona, Calif	Dry lake brine.
Do	Westend, Calif	Do.
Ozark-Mahoning Co	Brownfield, Tex	Subterranean brine.
Do	Seagraves, Tex	Do.
Great Salt Lake Minerals & Chemical Corp	Ogden, Utah	Salt lake brine.
Metallic sodium:		
E. I. du Pont de Nemours & Co	Niagara Falls, N.Y	Salt.
Do	Memphis, Tenn	Do.
Ethyl Corp	Baton Rouge, La	Do.
Do	Houston, Tex	Do.
R. M. I., Inc	Ashtabula, Ohio	Do.

Table 1.—Manufactured and natural sodium carbonates produced in the United States

(Thousand short tons and thousand dollars)

Year	Manufactured soda ash (ammonia-soda process)[1] [2]	Natural sodium carbonates[3]		Total quantity
	Quantity	Quantity	Value	
1974	3,507	4,059	157,486	7,566
1975	2,802	4,328	182,620	7,130
1976	2,344	5,216	259,253	7,560
1977	1,812	6,228	337,516	8,040
1978	*1,500	6,790	370,147	8,290
1979	W	W	476,711	8,253

*Estimate. W Withheld to avoid disclosing company proprietary data.

[1] Current Industrial Reports, Inorganic Chemicals, U.S. Bureau of the Census.

[2] Includes quantities used to manufacture caustic soda, sodium bicarbonate, and finished light and dense soda ash.

[3] Soda ash and trona (sesquicarbonate).

Table 2.—Source of U.S. soda ash by process, 1968-79

(Thousand short tons)

Year	Solvay		Natural	
	Production	Percent of total	Production	Percent of total
1968	4,596	69.2	2,043	30.8
1969	4,540	64.5	2,495	35.5
1970	4,393	62.1	2,678	37.9
1971	4,298	60.0	2,865	40.0
1972	4,305	57.2	3,218	42.8
1973	3,813	50.6	3,722	49.4
1974	3,507	46.4	4,059	53.6
1975	2,802	39.3	4,328	60.7
1976	2,344	31.0	5,216	69.0
1977	1,812	22.5	6,228	77.5
1978	*1,500	18.1	6,790	81.9
1979	W	W	W	W

*Estimate. W Withheld to avoid disclosing company proprietary data.

Table 3.—Manufactured and natural sodium sulfate produced in the United States[1]

(Thousand short tons and thousand dollars)

Year	Manufactured and natural[2]			Natural only	
	Lower purity[3] (99% or less)	High purity	Total	Quantity	Value
1974	565	783	1,348	684	16,411
1975	431	796	1,227	667	27,667
1976	466	766	1,232	663	32,655
1977	458	741	1,199	636	29,313
1978	606	630	[4]1,235	605	27,865
1979	[p]666	[p]514	[p]1,180	533	29,689

[p]Preliminary.

[1] All quantities converted to 100% Na_2SO_4 basis.

[2] Current Industrial Reports, Inorganic Chemicals, U.S. Bureau of the Census.

[3] Includes Glauber's salt.

[4] Low and high purity totals may not add to totals shown because of independent rounding.

Table 4.—Production and average value, f.o.b. plant, of metallic sodium in the United States, 1968-79

Year	Production (short tons)	Value (cents per pound)
1968	156,391	15.47
1969	164,685	15.84
1970	171,251	15.94
1971	153,075	16.26
1972	160,504	16.98
1973	176,903	17.43
1974	173,174	17.89
1975	144,133	20.70
1976	145,863	24.60
1977	158,752	28.82
1978	138,386	33.78
1979	[p]151,459	[p]41.18

[p]Preliminary.

CONSUMPTION AND USES

The demand for soda ash decreased about 3% in 1979 as a result of the growth in exports and temporary slowdown in the glass industry. Glass manufacturers consumed about 55%, chemicals consumed 23%, and water treatment, pulp and paper, soaps and detergents and other uses accounted for the rest. The total U.S. primary demand for sodium carbonate in 1978 was 7,551,000 short tons and about 7,304,000 in 1979.

Demand for sodium sulfate was about 2% lower in 1978 than that of the previous year. Although detergents have been reformulated to contain more sodium sulfate because of the reduced phosphate content required by antipollution regulations, recycling of the compound by paper manufacturers has cut back the consumption of sodium sulfate in kraft pulping.

Metallic sodium is used in the manufacture of tetraethyl lead and tetramethyl lead, both gasoline antiknock additives. Regulations limiting the amount of lead from automobile exhaust has curtailed the demand for metallic sodium. The Environmental Protection Agency deferred lowering the present quantity of 0.8 gram per gallon of antiknock lead additives to 0.5 gram per gallon for 1 year so that additional quantities of gasoline will be available.[6] Production of metallic sodium decreased 13% in 1978 to 138,384 tons, and increased in 1979 to about 151,459 tons.

STOCKS

Yearend stocks of natural sodium compounds, as reported by producers, were as follows:

	Thousand short tons	
	1978	1979
Natural soda ash	76	68
Natural sodium sulfate	57	29

PRICES

The values of natural soda ash and natural sodium sulfate, f.o.b. mine or plant, as reported by producers, were as follows:

	Value, dollars per short ton		Change, percent
	1978	1979	
Bulk soda ash	$54.51	$64.55	+15.6
Bulk sodium sulfate	46.06	55.69	+17.3

Yearend 1978 quoted prices of sodium and sodium compounds were as follows:

		1978	1979
Sodium carbonate (soda ash):			
Light, paper bags, carlots, works	per ton	$57.00-$78.00	$57.00-$78.00
Light, bulk, carlots, works	do	57.00- 64.00	57.00- 64.00
Dense, paper bags, carlots, works	do	57.00- 78.00	87.00
Dense, bulk, carlots, works	do	55.00	61.00- 62.00
Sodium sulfate (100% Na_2SO_4):			
Technical detergent, rayon-grade, bags, carlots	do	70.00- 72.00	70.00- 72.00
Technical detergent, rayon-grade, bulk, works	do	65.00	78.00
Domestic salt cake, bulk, works[1]	do	47.00- 52.00	47.00- 52.00
National Formulary (N.F. XII), drums	per pound	.235	.235
Metallic sodium:			
Bricks, carlots, works	do	.60	.68
Fused, lots 18,000 pounds and more, works	do	.54	.62
Bulk, tank, works	do	.41	.45

[1] East of Mississippi River.

Source: Chemical Marketing Reporter. Current Prices of Chemicals and Related Materials. V. 214, No. 26, Dec. 25, 1978, p. 34; v. 215, No. 26, Dec. 31, 1979, p. 34.

Prices at the beginning of 1978 for bulk soda ash shipped f.o.b. Wyoming were $55 per ton for all the natural producers. By yearend 1979, the price increased 28% to an average of $76 per ton.[9]

FOREIGN TRADE

At the beginning of 1978, the Belgian glass manufacturers were purchasing soda ash from Solvay et Cie at higher prices than those paid by neighboring countries. This prompted the three largest glass companies- Glaceries de Saint-Roch, Gladerbel, and Verrelitack- to contact U.S. natural soda ash producers and establish foreign trade negotiations. To avoid increased unemployment in an already depressed area, the Belgian economics minister intervened and persuaded Solvay et Cie to reduce its prices and make its product competitive with the U.S. material. A 5-year, 264,000-ton-per-year contract was drawn up with the glass manufacturers as a result, and negotiations with the United States halted.[10]

Table 5.—U.S. exports of sodium carbonate and sodium sulfate

(Thousand short tons and thousand dollars)

Year	Sodium carbonate		Sodium sulfate	
	Quantity	Value	Quantity	Value
1976	645	47,004	57	3,636
1977	759	52,943	43	2,801
1978	779	61,454	84	5,475
1979	997	86,663	102	8,516

Table 6.—U.S. imports for consumption of sodium sulfate

(Thousand short tons and thousand dollars)

Year	Crude (salt cake)[1]		Anhydrous		Total[1]	
	Quantity	Value	Quantity	Value	Quantity	Value
1976	214	10,360	102	5,751	316	16,111
1977	121	5,702	102	5,528	223	11,230
1978	41	1,701	96	4,890	[2]136	[2]6,590
1979	84	3,738	104	5,748	187	9,486

[1] Includes Glauber's salt as follows: 1975-1977, none; 1978, 1 ton ($1,157).

[2] Crude and anhydrous quantities may not add to totals shown because of independent rounding.

Table 7.—U.S. imports for consumption of sodium carbonate and bicarbonate in 1978-79

(Thousand short tons and thousand dollars)

	1978		1979	
	Quantity	Value	Quantity	Value
Soda ash	8	734	40	4,292
Sodium bicarbonate	7	774	3	616
Total	15	1,508	43	4,908

WORLD REVIEW

The alleged dumping of low-priced soda ash was an important topic in the last quarter of 1978. Eastern European countries, namely Bulgaria, the German Democratic Republic, Romania, the U.S.S.R., and Poland, were exporting over 330,000 tons of light soda ash per year to Western Europe at low prices but these sales did not constitute a major threat. Solvay et Cie and Imperial Chemical Industries (ICI) were concerned that 275,000 tons of dense Comecon soda ash was planned for annual export from Inowroclaw, Poland. This threatened the Western European soda ash producers who rely heavily on the sales to West European glass manufacturers. Western European prices average $130 per ton while East European soda ash sells for approximately $55 per ton, f.o.b. country border. The EEC Commission has named the Comecon countries in an antidumping claim, and investigations continued into 1979.[11] The East European nations countered the dumping allegations by claiming Solvay et Cie, in collusion with the Belgium Government, blocked import negotiations with the United States.[12]

Algeria.—Polands' Polimex-Cekop confirmed it is close to signing a contract to build a 165,000-ton-per-year soda ash plant in Algeria. It will be built at Mostaganem on the Mediterranean coast for Société Nationale des Industries Chimiques (SNIC), ia State-owned chemical company. SNIC will provide most of the soda ash for SNIV, the Algerian glass producer.[13]

Belgium.—The Belgian government approved a $42 million program to expand and modernize Solvay et Cie's synthetic soda

Table 8.—Sodium carbonate: World production, by country

(Thousand short tons)

Country[1]	1976	1977	1978[p]	1979[e]
Albania[e]	23	25	28	36
Australia[e]	170	175	180	180
Austria[e]	185	185	190	190
Belgium	[r]388	487	471	480
Brazil	[r]165	155	[e]175	180
Bulgaria	[r]1,152	1,343	1,426	[2]1,651
Canada[e]	500	500	500	500
Chad[e]	6	12	12	12
Chile[e]	10	11	12	12
China:				
Mainland	NA	1,200	1,465	[2][3]1,965
Taiwan	82	82	78	78
Colombia[e]	165	150	184	155
Czechoslovakia	131	130	133	135
Denmark[4]	1	1	2	2
Egypt	23	[e]25	[e]30	40
France	1,451	1,504	1,491	1,490
German Democratic Republic	914	925	939	940
Germany, Federal Republic of	1,503	1,488	1,356	1,300
Greece[e]	1	1	1	1
India	[r]622	625	650	670
Italy	741	783	[e]800	800
Japan	[r]1,197	1,300	1,281	1,300
Kenya[5]	[r]120	121	168	170
Korea, Republic of	[r]171	188	194	195
Mexico	430	[e]460	456	460
Netherlands	299	304	309	460
Norway[e]	[r]25	[r]30	30	30
Pakistan	[r]70	67	82	78
Poland	[r]800	740	731	730
Portugal	126	143	145	145
Romania	897	949	991	145
Spain	578	[r][e]350	550	550
Sweden[e]	1	1	1	1
Switzerland[e]	[r]50	[r]50	50	50
Turkey[e]	60	65	70	75
U.S.S.R.	5,337	5,589	5,897	5,900
United Kingdom[e]	1,540	1,650	1,760	1,800
United States[3]	7,560	8,040	8,290	8,253
Yugoslavia	151	173	183	190
Total	[r]27,645	30,032	31,311	21,349

[e]Estimate. [p]Preliminary. [r]Revised. NA Not available.

[1] Synthetic unless otherwise noted.

[2] Reported figure.

[3] Includes natural and synthetic.

[4] Production for sale only; excludes output consumed by producers.

[5] Natural only.

ash plant at Couillet and their chloralkali plant at Jemeppe-sur-Sambre. An additional $20 million will be used to invest in energy-saving programs.[14]

Botswana.—The Government is interested in developing its vast 900-square-kilometer Sua Pan alkaline brine resources into soda ash. A large Japanese company is attempting to assemble a consortium of interested companies to study the feasibility of exploiting this remote deposit.[15]

Canada.—A $290,000 feasibility contract was awarded to Surveyor, Nenninger, and Chenevert, Inc., to study the possibility of establishing a 850,000-ton-per-year soda ash facility in the remote Gaspe region of Quebec. Salt would come from the Magdalen Islands in the Gulf of St. Lawrence, coal from the mines being developed in Nova Scotia, and limestone from new quarries planned for the Gaspe Peninsula. If established, the $1 billion project could be onstream by 1982; however, since the United States is the main target for export, severe competition with the Wyoming trona deposits would probably occur.[16]

Kenya.—ICI's Lake Magadi natural soda ash operation plans to double its capacity to 500,000 tons per year by 1983. The international market for natural soda ash is favorable because price and energy costs are lower than those for synthetic soda ash, which is the principal worldwide product of production.[17]

Thailand—.The Canadian Export Development Corp. indicated support for a $165 million loan for a Thai soda ash project assigned to it by the 1976 Bali summit meeting of the Association of Southeast Asian Nations (ASEAN). A 2,000-billion-ton resource of 97% pure rock salt in the northeast sector of the country would provide the raw material for the production of soda ash and ammonium chloride, useful in

Table 9.—Sodium sulfate: World production, by country

(Thousand short tons)

Country[1]	1976	1977	1978[p]	1979[e]
Natural:				
Argentina	39	40	41	50
Canada	507	435	415	[2]498
Chile[3]	[r]16	15	4	6
Egypt	5	[e]7	4	[e]4
Iran	28	44	39	25
Mexico	251	121	141	145
Spain	181	200	209	230
Turkey	97	80	71	65
U.S.S.R.[e] [4]	340	350	365	370
United States[5]	663	636	605	533
Total	[r]2,127	1,928	1,894	1,926
Synthetic:				
Austria[e]	[r]60	[r]60	60	60
Belgium[e]	340	275	275	275
Chile[6]	31	33	46	50
Finland[e]	70	50	55	50
France	143	131	138	155
German Democratic Republic	164	152	144	140
Germany, Federal Republic of	283	267	233	230
Greece[e]	[r]6	7	7	7
Hungary[e]	11	11	11	11
Italy[e]	[r]104	105	105	105
Japan	345	357	354	365
Netherlands	55	55	55	55
Portugal	54	51	56	50
Spain[7]	[e]183	192	134	190
Sweden	[r]114	116	116	116
U.S.S.R.[e] [4]	240	250	265	265
United States[8]	569	605	630	647
Total	[r]2,772	2,717	2,684	2,771

[e] Estimate. [p] Preliminary. [r] Revised.

[1] In addition to the countries listed, the People's Republic of China, Norway, Poland, Romania, Switzerland, and the United Kingdom are known to or are assumed to have produced synthetic sodium sulfate, and other unlisted countries may have produced this commodity, but production figures are not reported and available general information is inadequate for the formulation of reliable estimates of output levels.

[2] Reported figures.

[3] Natural mine output, excluding byproduct output from the nitrate industry, which is reported separately under manufactured.

[4] Conjectural estimates based on 1968 information on natural sodium sulfate and general economic conditions.

[5] Sold or used by producers.

[6] Byproduct of nitrate industry.

[7] Quantities of synthetic sodium sulfate credited to Spain are reported in official sources in such a way as to indicate that they are in addition to the quantities reported as mined (reported in this table under "Natural"), but some duplication may exist.

[8] Derived approximate figure; data presented are the difference between reported total sodium sulfate production (natural and synthetic, undifferentiated) and reported natural sodium sulfate sold or used by producers (reported under "Natural" in this table).

glass manufacture and an ingredient in nitrogen fertilizers, respectively. The Solvay process is the favored method of production; however, two possible alternatives under consideration are (1) the ammonium chloride method which combines rock salt with ammonium compounds to yield soda ash and ammonium chloride, and (2) the "new Asahi" method, which uses freshwater and limestone. Company engineers claim this second process uses 20% less energy and 18% less rock salt per unit of soda ash produced. Both alternative methods utilize ammonia, and the total cost of the soda ash plants and ammonia facilities is estimated to be only slightly higher than that for the Solvay plant. The Thai project is scheduled to be onstream by 1982 with a 1.3-million-short-ton-per-year capacity.[18]

Turkey.—Krebs of France was awarded a contract to expand the existing soda ash facilities at Mersin. Completion is scheduled for 1980 and will boost the plants capacity up to 364,00 tons per year.[19]

United Kingdom.—The United Kingdom Price Commission allowed ICI to increase its soda ash prices to offset the higher production costs and the capital investments of modernizing three soda ash plants located at Lostock, Winnington, and Wallerscote in the Cheshire district of northwest England. ICI has felt the increasing pressure from the U.S. natural soda ash market, and this revitalization of their 50-year-old plants should spur European competition.[20]

TECHNOLOGY

Soda ash was used as a reagent to recover 150 pounds per day of yellowcake (U_3O_8) from old tailings at closed uranium processing mills. The 1.2 million tons of discarded material contained about 300,000 pounds of uranium oxide valued at $12 million, in 1979 dollars.[21]

In 1979, Stanford Research Institute revealed a new, low-cost process for the production of pure silicon for solar energy cells. This process utilizes sodium and sodium fluorosilicate and produces sodium fluoride, used in aluminum production, as a by-product.[22]

Research with the sodium-sulfur battery continued, with British technology making significant advances. The first commercial batteries could be marketed by 1982 at the earliest, provided certain problems can be resolved. Two advantages this type of battery has over the conventional lead-acid variety are that it is more compact and provides an energy density four times greater than its rival.[23]

Molten sodium was being tested as the energy collection medium in a liquid-metal fast breeder reactor. Metallic sodium accepts heat more readily than water, making it a more effective heat transfer medium. Construction of this type of nuclear reactor in the United States, such as the Clinch River reactor in Tennessee, has been halted due to potential dangers, such as in handling the sodium. Molten sodium is hard to handle and would react violently if the reactor cooling water should come in contact with it, and would also corrode most metals when in contact with oxygen.

Nevertheless, prototype fast breeder reactors using sodium have been built in Western Europe and have proven to be reliable and relatively trouble-free over the past several years. In southeastern France, the 40-megawatt Rapsodie (for rapid sodium) was built in 1967, and at Marcoule, France, the 250-megawatt Phénix was constructed in 1973. A European multi-nation venture is underway at Creys-Malville, France, with the construction of a 1,200-megawatt sodium reactor named Superphénix. Completion is scheduled for 1982.[24]

Further research in using Glaubers' salt as a passive solar heating system continued in 1979. Scientists at the Massachusetts Institute of Technology and other private firms designed ceiling tiles containing sodium sulfate and other chemicals which adsorb radiant daytime heat and release it in the evening when the temperature drops. The chemical mix undergoes a phase change from solid to liquid as the sodium sulfate adsorbs the heat energy. A reverse of this process occurs when the temperature decreases below 73° F.[25]

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Stone

Richard H. Singleton[1]

U.S. production of crushed stone increased 10% in 1978 and 5% in 1979 to a new record 1.10 billion tons. About three-quarters of crushed stone production continued to be limestone, followed by granite, traprock, sandstone, marble, and shell, in order of volume. Value of crushed stone production increased 18% in 1978 and 18% in 1979 to a 1979 value of $3.40 billion.

Stone was produced in every State except Delaware and North Dakota. Leading States continued to be Texas and Pennsylvania. There were about 1,870 companies operating approximately 4,500 and 4,200 crushed stone quarries in 1978 and 1979, respectively. Output per quarry in 1979 was about 260,000 tons, compared with 180,000 tons in 1969. Only about 6% of these quarries were 900,000-ton-per-year capacity or larger, but these accounted for 39% of total output in 1979. Approximately two-thirds of U.S. crushed stone was used in road, railroad, and bridge construction; other uses were, in order of volume, cement production, chemical lime production, agriculture, aggregate for buildings construction, and metallurgical flux.

U.S. production of dimension stone decreased 2% in 1978 and increased 8% in 1979 to 1.51 million tons. Approximately 42% of dimension stone production continued to be granite followed by limestone, sandstone, marble, and slate, in order of volume. Value of dimension stone increased 9% in 1978 and 17% in 1979 to $132 million. Value of imports, about one-half marble and mainly from Italy, increased 36% in 1978 and 27% in 1979 to $65.6 million.

Dimension stone was produced in 41 States in 1978 and 39 States in 1979. Leading States were Indiana, Georgia, and Vermont. There were about 275 companies operating approximately 400 dimension stone quarries. Approximately one-third of U.S.-produced dimension stone was used in the construction of buildings and about one-quarter was used in monuments.

The Bureau of Mines canvass of dimension stone does not include processors of purchased rough stone. All producers are covered; if the producer sells rough stone to a processor, it is tabulated as rough stone; if the producer processes finished stone, only the finished stone is tabulated, and the rough stone is deducted. The Bureau of Mines generally accepts the stone classification reported by producers.

Granite usually includes all coarser grained igneous rocks. Limestone may be pure calcium carbonate, or may be bituminous, dolomitic, or siliceous. The term "traprock" pertains to all dense, dark, fine-grained igneous rocks. Marble may include any calcareous rock that will polish. Sandstone may be calcareous, quartz or quartzite, or conglomerate. Quartzite may be described as any siliceous-cemented sandstone. Quartzite that has been comminuted to sand is considered to be sand and gravel.

Capacity figures and stocks were not available. Inventories on hand at quarries and plants were estimated at about a 1-month supply, or 100 million tons.

As appropriate throughout the remainder of this report, where different values exist for 1978 and 1979, the 1978 values are shown first, with the 1979 values immediately following in parentheses.

DOMESTIC PRODUCTION

Dimension Stone.—Dimension stone was produced by 279 (271) companies at 416 (397) quarries in 41 (39) States. Leading States were Indiana, Georgia, and Vermont, producing, together, 51% of the Nation's total. Notable was a 45% increase in production in Indiana in 1979. Production in Ohio decreased 39% in 1978 and 45% in 1979 to 50,000 tons. Of the total U.S. production, 41% (42%) was granite, 27% (31%) was limestone, 18% (15%) was sandstone, 8% (5%) was marble, and 4% (6%) was slate. Notable in 1979 were a 27% increase in limestone production, a 31% decrease in marble output, and a 64% increase in slate production. Leading companies were, in 1978, Georgia Marble Co. and Rock of Ages Corp., and in 1979 Indiana Limestone Co., Inc., and Rock of Ages Corp.

Crushed Stone.—Crushed stone was produced by 1,865 (1,876) companies at about 4,500 (4,200) quarries in every State except Delaware and North Dakota. Leading States were Texas, Pennsylvania, Florida, Illinois, Missouri, Virginia, and Ohio; these seven States produced 40% (39%) of U.S. crushed stone. Of the total U.S. production, 75% (74%) was limestone, 12% (11%) was granite, 8% (9%) was traprock, 3% was sandstone, and 1.2% (1.1%) was shell. Notable in 1979 was a 20% increase in traprock output. Leading producers, in order of tonnage, were Vulcan Materials Co., Martin Marietta Corp., Lone Star Industries, Inc. (Koppers Co., Inc.), Koppers Co., Inc. (Lone Star Industries, Inc.), and United States Steel Corp.

Disagreement continued between industry and Government regulators regarding accurate measurement of particulate levels. The Environmental Protection Agency had issued, in 1975, regulations governing particulate emissions in the crushed stone industry. Industry continued technical studies and lobbying efforts to modify these regulations, particularly when compliance caused economic hardship.

The Surface Mining Control and Reclamation Act, passed in 1977, applied only to coal but mandated a study of noncoal mining industries. A study, completed late in 1979 by the Committee on Surface Mining and Reclamation under the National Research Council, suggested that regulation of the stone mining industry might be administered on a local level and not by the Federal Government.

The Federal Metal and Nonmetallic Safety Act, enacted in 1966 and amended in 1977, was developed primarily for coal mining and somewhat arbitrarily applied to stone quarrying. In general, the crushed stone industry had found Federal safety regulations both costly and troublesome and has continued a lobbying effort to modify them.

LIMESTONE

Limestone includes dolomite.

Dimension.—Compared with 1977, 1979 output of dimension limestone increased 6% in tonnage and 37% in value to 470,000 tons and $25.8 million. Dimension limestone was produced in 1978 (1979) by 60 (55) companies at 79 (73) quarries in 17 States. Indiana continued to be the leading State producing 62% (72%) of the U.S. total, followed by Wisconsin. A leading producer was Indiana Limestone Co. It was estimated that three major companies accounted for nearly one-half of total U.S. output.

Crushed.—Compared with 1977, 1979 output of crushed limestone increased 15% in tonnage and 40% in value to 812 million tons and $2,335 million. It was produced by 1,259 (1,253) companies at 2,967 (2,844) quarries in 46 States. Leading States, in order of tonnage, were Texas, Illinois, Florida, Missouri, and Pennsylvania; these five States accounted for 37% (38%) of U.S. output. Leading companies were, in order of tonnage, Vulcan Materials Co., Martin Marietta Corp., and United States Steel Corp., which together accounted for 11% of total U.S. output.

GRANITE

Dimension.—Compared with 1977, 1979 output of dimension granite increased 15% in tonnage and 27% in value to 627,000 tons and $69.2 million. Dimension granite was produced in 1978 (1979) by 81 (85) companies at 147 (150) quarries in 20 States. Georgia continued to be the leading State, producing 35% (31%) of the U.S. total, followed by Vermont, New Hampshire, and Massachusetts; these four States together produced 75% (70%) of the U.S. total. One of the leading companies was Rock of Ages Corp., which together with two other leading companies produced about one-third of U.S. output.

Crushed.—Compared with 1977, 1979 output of crushed granite increased 13% in tonnage and 40% in value to 122 million tons and $386 million. It was produced by 145 (140) companies at 382 (425) quarries in 32 (33) States. Leading States continued to be, in order of tonnage, Georgia, North

Carolina, Virginia, and South Carolina; these four States accounted for 74% (75%) of U.S. output. Leading producers, in order of tonnage, were Vulcan Materials Co., Martin Marietta Corp., and Lone Star Industries, Inc. in 1978 and Koppers Co., Inc. in 1979; these three accounted for 46% (48%) of U.S. output.

TRAPROCK

Dimension.—Compared with 1977, 1979 output of dimension traprock more than doubled in both tonnage and value to 1,663 tons and about $42,000. Hawaii continued to be the leading State, producing more than one-half of the U.S. total. The leading producer continued to be J. W. Glover, Ltd., in Hawaii.

Crushed.—Compared with 1977, 1979 output of crushed traprock increased 31% in tonnage and 57% in value to 101 million tons and $327 million. It was produced by 289 (318) companies at 616 (691) quarries in 24 States. Leading States were, in order of total 1978-79 tonnage, Oregon, New Jersey, and Washington; these three States accounted for 39% (46%) of U.S. output. Notable were more than 50% increases in 1979 tonnage in both Oregon and Washington. Leading producers, in order of tonnage, were Thomas Tilling Ltd., mainly in Connecticut, the U.S. Forest Service, mainly in the Pacific States, and the Oregon State Highway Department in 1979 and Traprock Industries, Inc., in 1978. The top three producers accounted for 18% (16%) of U.S. output.

SANDSTONE

Dimension.—Compared with 1977, output of dimension sandstone decreased 10% in tonnage and 4% in value to 221,000 tons and $8.8 million. Dimension sandstone was produced in 1978 (1979) by 81 (79) companies at 139 (133) quarries in 23 (26) States. Leading States continued to be, in order of volume, Ohio, Pennsylvania, and Maryland; these three States accounted for 58% (50%) of U.S. output. Leading producers were, in order of total 1978-79 tonnage, Briar Hill Stone Co. and Standard Slag Co., both in Ohio. The top three producers accounted for an estimated 33% (29%) of U.S. production.

Crushed.—Compared with 1977, output of crushed sandstone increased 3% in tonnage to 31 million tons and 17% in value to $107 million. Crushed sandstone was produced in 1978 (1979) by 183 (187) companies at 318 (279) quarries in 30 (29) States. Leading States continued to be, in order of volume, Pennsylvania, Arkansas, and California; these three States accounted for 46% (48%) of U.S. output. Leading producers were East Bay Excavating Co. of California, Martin Marietta Corp., and Ashland Oil, Inc; these three accounted for 17% of U.S. output in 1979.

MARBLE

Dimension.—Dimension marble included both crystalline and limestone marble and any other calcareous stone capable of accepting a polish. Output of dimension marble increased 19% in 1978 but decreased 31% in 1979 to 80,000 tons valued at $14.1 million. Dimension marble was produced by 14 (11) companies at 26 (19) quarries in 14 (10) States. Georgia, Vermont, and California, in order of tonnage, continued as the three leading States producing 77% (82%) of U.S. output. Leading producers were, in order of tonnage, Georgia Marble Co. and M & M Rock Co., Inc., of California. The top three companies accounted for an estimated 83% (80%) of U.S. output.

Crushed.—Compared with 1977, 1979 output of crushed marble decreased 3% to 1.5 million tons valued at $25.1 million. It was produced by 15 companies at 34 (29) quarries in 12 (11) States. Leading States, in order of tonnage, were Alabama, Georgia, and Wyoming. These States together produced 87% (90%) of U.S. crushed marble. Alabama accounted for 51% of U.S. output in 1979. Leading producers were, in order of tonnage, Georgia Marble Co., Standard Oil Co. of Indiana, in Alabama, and Moretti-Harrah Marble Co. in Alabama; these three accounted for 77% (85%) of U.S. output.

SLATE

Dimension.—Compared with 1977, output of dimension slate increased 53% to 87,000 tons valued at $12.8 million. Dimension slate was produced by 33 (31) companies at 39 (38) quarries in 6 States. The three leading States, Vermont, Pennsylvania, and Virginia, in order of volume, accounted for 90% (93%) of U.S. output. Leading producers in 1978 were, in order of tonnage, A. Dally and Sons Inc., and Emerald Slate Corp., both in Pennsylvania. The top three U.S. producers accounted for an estimated 37% of U.S. output.

Crushed.—Compared with 1977, output of crushed slate increased 44% to 1.3 million tons valued at $11.5 million. Crushed slate was produced by 9 (11) companies at 9 (11) quarries in 5 (6) States. The three leading States, Virginia, Georgia, and Arkansas, accounted for 99% of U.S. output. Leading producers in 1978 were, in order of tonnage, Ashland Oil Inc., in Georgia, and Arvonia Buckingham Slate Co., in Virginia. Leading producers in 1979 were, in order of tonnage, Amlite Corp. and Le Sueur-Richmond Slate Corp., both in Virginia. The top three producers accounted for an estimated 63% (57%) of U.S. output.

SHELL

Shell is mainly fossil reefs of oyster shell. Compared with 1977, output of crushed shell decreased 10% to 12.2 million tons valued at $38.6 million. Crushed shell was produced by 10 (8) companies at 17 locations in 6 States. The three largest producing States were Louisiana, Maryland, and Texas with Louisiana accounting for 70% (71%) of U.S. output. Leading producers, in order of tonnage, continued to be Radcliff Materials Inc., Parker Brothers & Co., Inc., and Pontchartrain Dredging Corp.; these three accounted for 72% (79%) of U.S. output.

MARL

Compared with 1977, output of marl increased 5% to 2.6 million tons valued at $4.5 million. Marl was produced by 21 (20) companies at 21 (20) quarries in 9 (8) States. Leading States, in order of tonnage, continued to be South Carolina, Texas, Mississippi, and South Carolina; these four States accounted for 89% of U.S. output. Giant Portland Cement Co., in South Carolina, continued to be the largest U.S. producer.

MISCELLANEOUS STONE

Dimension.—Compared with 1977, 1979 output of miscellaneous dimension stone decreased 4% to 24,000 tons valued at $930,000.

Crushed.—Compared with 1977, 1979 output of miscellaneous crushed stone decreased 3% to 12.5 million tons at $33 million.

CONSUMPTION AND USES

Dimension stone was marketed over wide areas; crushed stone was generally marketed in a limited area, usually in the State where produced. Stockpiles were not monitored and output during the year was assumed to equal consumption.

Dimension.—Total consumption of dimension stone in 1979 increased 39% in value over 1977 consumption to $197 million; of this, 33% was imported. Compared with 1977, 1979 consumption of domestically produced dimension stone increased 7% to 1.51 million tons valued at $131.8 million, about 64% of which was used in building construction. Consumption of stone for monuments remained fairly steady, accounting for 21% of total dimension stone output in 1979 compared with 23% in 1977. Notable during the 1977-79 period were a 57% increase in flagging use to 108,000 tons valued at $4.8 million and a 262% increase in flooring slate to 23,000 tons valued at $4.1 million.

Crushed.—Compared with 1977, 1979 output of crushed stone increased 15% to 1.10 billion tons valued at $3.27 billion. Notable during the 1977-79 period were a 31% increase in other construction aggregate and roadstone to 205 million tons valued at $587 million; an 83% increase in filter stone to 3.80 million tons valued at $11.6 million; a 65% increase in stone sand to $19.5 million tons valued at $66.6 million; a 94% increase in terrazzo to 1.21 million tons valued at $14.9 million; and a 63% increase in whiting to 1.36 million tons valued at $32.5 million.

LIMESTONE

Dimension.—During 1977-79, there was a 20% increase in rough blocks and irregular shapes to 214,000 tons valued at $6.4 million; a 60% increase in flagging to 29,000 tons valued at $531,000; and a 20% increase in house stone veneer to 65,000 tons valued at $3.1 million.

Crushed.—During 1977-79, there was a 36% increase in "other construction aggregate and roadstone" to 135 million tons valued at $371 million; a 74% increase in limestone sand to 15.6 million tons valued at $51.4 million; a 30% increase in railroad ballast (primarily in Pennsylvania, Wyoming, West Virginia, Ohio, Indiana, and Texas) to 14.0 million tons valued at $37.6 million; a 41% increase in "other fillers and extenders" to 2.79 million tons valued at $31.7 million; a 56% increase in whiting to

1.09 million tons valued at $30.0 million; a 25% increase in poultry grit and mineral food to 2.44 million tons valued at $19.6 million; a 97% increase in filter stone to 2.69 million tons valued at $7.9 million; a 79% increase in terrazzo to 624,000 tons valued at $7.5 million; and a 25% increase in roofing granules to 376,000 tons valued at $2.3 million. Also notable during the 1977-79 period was a 130% increase in Alabama in limestone riprap to 924,000 tons; in Indiana, a 33% increase in total limestone aggregate to 27.0 million tons; in Michigan, a 21% decrease in flux stone to 7.47 million tons; and, in Missouri, a 52% increase in riprap to 4.84 million tons. Significant increases in riprap usage also occurred in New York, Tennessee, and Wisconsin.

The breakdown by end use of crushed limestone consumption in 1979 was construction, 73%; cement manufacture, 13%; lime manufacture, 4%; agricultural, 4%; flux stone, 3%; and other, 3%.

GRANITE

Dimension.—During 1977-79, there was a 151% increase in rough blocks and irregular shapes to 108,000 tons valued at $4.1 million; this accounted for most of the overall total increase in sales of dimension granite. Use of granite in monuments showed no significant change. The use breakdown in 1979 was monumental, 51%; curbing, 16%; and other construction, 33%.

Crushed.—During 1977-79, there was a 63% increase in "other construction aggregate and roadstone" to 25.9 million tons; a 14% decrease in each of concrete aggregate and bituminous aggregate to 15.8 million tons and 14.6 million tons, respectively; a 140% increase in surface treatment aggregate to 7.6 million tons; and a 39% increase in granite sand to 1.8 million tons. The end-use breakdown for 1979 was aggregate, 84%; railroad ballast, 9%; terrazzo and roofing granules, 3%; other, 4%.

TRAPROCK

Dimension.—Flagging accounted for 84% of total use of dimension traprock in 1979; other uses were mainly in the manufacture of rough blocks and irregular shapes.

Crushed.—Notable during the 1977-79 period were an 80% increase in dense-graded roadbase stone to 31.5 million tons; a 75% increase in concrete aggregate to 9.1 million tons; and a 69% increase in surface treatment aggregate to 7.2 million tons. The 1979 end-use breakdown was aggregate, 89%; riprap, 4%; railroad ballast, 4%; roofing granules, 2%; and traprock sand, 1%.

SANDSTONE

Dimension.—During 1977-79, there was a 32% decrease in cut and sawed sandstone to 44,000 tons valued at $3.0 million; a 35% increase in flagging to 33,000 tons valued at $2.2 million; a 38% decrease in rubble to 28,000 tons valued at $655,000; and a 36% decrease in house stone veneer to 9,500 tons valued at $415,000.

Crushed.—During 1977-79, there was a 27% increase in "other construction aggregate and roadstone" to 7.2 million tons; a 20% increase in bituminous aggregate to 4.7 million tons; a 48% decrease in riprap to 850,000 tons; and smaller but significant decreases in railroad ballast, refractory stone, and flux stone. The 1979 end-use breakdown was aggregates, 77%; riprap and railroad ballast, 6%; flux stone and ferrosilicon, 4%; cement manufacture, and refractories, 4%; and other, 9%.

MARBLE

Dimension.—During 1977-79, there was a 32% decrease in rough blocks and irregular shapes to 39,000 tons valued at $2.0 million; a 51% increase in cut and sawed marble to 20,000 tons valued at $9.0 million; and a 29% decrease in rubble to 3,600 tons valued at $118,000.

Crushed.—Use of marble as terrazzo increased approximately 17% to about 200,000 tons during 1977-79.

SLATE

Dimension.—During 1977-79, there was a 262% increase in flooring slate to 230,000 tons valued at $4.1 million; a 24% decrease in structural and sanitary slate to 8,700 tons valued at $3.6 million; and a 52% increase in flagging to 35,000 tons valued at $1.6 million. The 1979 end-use breakdown by value was flooring, 32%; structural and sanitary, 28%; roofing, 24%; flagging, 13%; and other, 3%.

Crushed.—Crushed slate was used for lightweight aggregate (46%), roofing granules (8%), slate flour (5%), and other. Output of slate for lightweight aggregate increased 20% to 590,000 tons valued at $7.6 million.

SHELL

During 1977-79, there was a 31% decrease in dense-graded roadbase shell to 3.3 million tons valued at $11.8 million; a 16% increase in other construction aggregate and roadstone to 5.4 million tons valued at $17.5 million; and a 40% decrease in shell use in cement manufacture to 1.3 million tons valued at $3.3 million. The 1979 end-use breakdown was aggregate 72%; cement manufacture, 10%; and other, 18%.

MARL

Crushed marl was used primarily for cement manufacture (88%) and soil conditioning (10%). During 1977-79, there was a 13% increase in marl use in cement manufacture to 2.3 million tons valued at $3.5 million and a 29% increase in use of marl soil conditioning to 255,000 tons valued at $982,000.

MISCELLANEOUS STONE

Dimension.—Miscellaneous types of dimension stone were used in 1979 primarily as rough blocks and irregular shapes (63%) and rubble (24%).

Crushed.—Miscellaneous types of crushed stone were used in 1979 primarily as aggregate in road construction (89%) and riprap and jetty stone (8%).

PRICES

Dimension.—Compared with 1977, the average 1979 price of dimension stone increased 19% to $87.29 per ton. The price of dimension marble increased 41% during this period to $177.30 per ton and this was accompanied by an 18% decrease in tonnage sales. The price of dimension slate increased only 2% during this period to $146.89 per ton and this was accompanied by a 53% increase in tonnage sales.

The 57% increase in flagging tonnage between 1977 and 1979 was accompanied by a 7% decrease in price. However, the 262% increase in flooring slate was accompanied by an 18% increase in price during this period, indicating no correlation between price and demand.

Crushed.—Compared with 1977, the average 1979 price of crushed stone increased 21% to $2.98 per ton. The price of crushed slate increased only 4% during this period to $8.94 per ton, and this was accompanied by a 44% increase in tonnage sales.

The 64% increase in whiting tonnage between 1977 and 1979 was accompanied by an 8% decrease in price. The 94% increase in terrazzo tonnage during this period was accompanied by a 2% decrease in price. Significant increases between 1977 and 1979 of tonnage sales in "other construction aggregate and roadstone," in filter stone, and in stone sand were not accompanied by percentage price changes significantly different from the 21% average price increase for all crushed stone.

FOREIGN TRADE

Exports.—Exports of dimension stone, about 40% granite, almost tripled in tonnage during 1978 but decreased 23% in 1979 to 225,000 tons. Total value of these exports increased 29% in 1979 to $17.3 million. Exports to Canada increased to 70% of total tonnage in 1978 but decreased to 32% in 1979. Exports to Japan increased from 18% of total tonnage in 1977 to 24% in 1979. Notable was a shipment of 40,000 tons of rough limestone blocks to Venezuela in 1979.

Tonnage of exports of crushed stone, about 90% limestone, increased 2% in 1978 and 6% in 1979 to 4.2 million tons. Total value increased 27% in 1979 to $22.9 million. Exports to Canada decreased from 99% of total tonnage in 1977 to 89% in 1979. Notable was a shipment of 301,000 tons of crushed limestone to Venezuela in 1979.

Imports.—Value of imports of dimension stone increased 36% in 1978 and 27% in 1979 to $65.6 million; of this, on a value basis, 71% (72%) came from Italy and about 7% (9%) was granite from Canada. On a value basis, marble accounted for 51% (48%) of imports (about 80% from Italy) followed by granite, 16% (20%) (about 40% from each of Canada and Italy), travertine, 11% (14%) (about 90% from Italy), and slate, 11% (10%) (about 90% from Italy). No significant changes in import pattern by stone type or exporting country occurred during the 1978-79 period.

Imports of crushed stone increased 14% in 1978 and 4% in 1979 to 3.9 million tons valued at $10.0 million. Of this tonnage, 58% (60%) was limestone, over 90% of which came from Canada. Imports of quartzite, about 90% from Canada, increased steadily from 67,000 tons in 1977 to 109,000 tons in 1979 valued at $822,000. The remainder of crushed stone imports was nearly all unidentified crushed stone.

Imports of calcium carbonate fines increased 6% in 1978 but decreased 15% in 1979 to 504,000 tons valued at $6.0 million; of this, natural chalk accounted for over 90% of tonnage but only 12% (10%) of value. More than 99% of this natural chalk came from the Bahamas and Canada. Approximately 33,000 tons of chalk whiting was imported each year from 1977 to 1979; over 95% of this came from France. About 10,000 tons of precipitated calcium carbonate was imported each year; of this, about one-half came from the United Kingdom, and most of the remainder was imported from France and Japan.

WORLD REVIEW

World annual production, excluding central economy countries, was approximately 3 billion tons of crushed stone and 13 million tons of dimension stone. Of this, the United States produced about one-third of the total crushed stone, and Italy produced approximately one-half of the total dimension stone. Approximately one-third of U.S. supply, by value, of dimension stone was imported from Italy.

Canada.—Stone production decreased 7% in 1978 to 123 million tons valued at $297 million. Of this, dimension stone accounted for 0.3% of total tonnage and 2% of total value. Construction accounted for 95% of crushed stone use and over 90% of dimension stone use. About three-quarters of total crushed stone usage was in road and other construction associated with transportation. The Province of Quebec produced 61% of Canadian stone in 1978 followed by Ontario, 27%. The 1978 production breakdown by type was limestone, 50%; granite, 46%; and sandstone, 3%.

Italy.—Production of marble, Italy's most valuable type of dimension stone, was approximately 1.5 million tons in 1978. Other types of dimension stone produced in quantity were travertine (a type of marble) and granite. However, about one-half million tons of dimension granite was imported annually. About two-thirds of dimension stone production was exported.

United Kingdom.—Crushed stone production increased 3% in 1978 to about 135 million tons; of this, approximately two-thirds was limestone. Chalk production also increased 3% in 1978 to about 18 million tons; of this, 83% was used in cement manufacture.

TECHNOLOGY

A minor but growing use for limestone is in removal of sulfur oxides from stack gases, mainly from coal burning. Required is a chemically reactive high-surface-area powder dispersed in an aqueous slurry. The reaction mechanism in the scrubber is solution of the finely ground calcium carbonate ($CaCO_3$) in water, followed by reaction with SO_x, to form calcium sulfite ($CaSO_3$) and calcium sulfate ($CaSO_4$). In 1979, an estimated capacity of 10 million megawatts of coal-fired electrical generating plants were equipped with limestone scrubbers that could have used a total of 1 to 2 million tons of limestone. Developmental studies[2] were underway in the United States to improve reaction rates by the use of catalysts such as adipic acid. Disposal of large quantities of sludge consisting of unreactecd limestone, fly ash, and reaction products was being studied.

Direct desulfurization of powdered coal in a fluidized bed was being studied on a pilot scale. This process uses about three times as much limestone as with scrubbers in conventional coal burning. The waste product is primarily a solid mixture of ash and sulfated reaction product.

Giant rippers were being developed to replace drilling and blasting to dislodge rock from deposits, including some limestone, that have a horizontal plane of weakness.

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[1] Supervisory physical scientist, Section of Nonmetallic Minerals.

[2] National Crushed Stone Association. Seminar on Limestone for Flue Gas Scrubbing, Houston, Tex. Washington, D.C., January 1980.

Table 1.—Salient stone statistics in the United States

(Thousand short tons and thousand dollars)

	1975	1976	1977	1978	1979
Sold or used by producers:					
Dimension stone	1,403	1,400	1,416	1,394	1,510
Value	$98,600	$104,400	$103,900	$113,100	$131,800
Crushed stone[1]	900,000	900,300	954,000	1,049,600	1,097,100
Value	$2,022,000	$2,117,000	$2,353,000	$2,773,000	$3,267,000
Total stone[2]	901,400	901,700	955,400	1,051,000	1,098,600
Total value[2]	$2,120,000	$2,221,000	$2,457,000	$2,886,000	$3,399,000
Exports (value)	$22,100	$24,000	$22,600	$31,400	$40,200
Imports for consumption (value)	$46,100	$46,600	$48,600	$64,800	$81,600

[1] Does not include American Samoa, Guam, Puerto Rico, and Virgin Islands.
[2] Data may not add to totals shown because of independent rounding.

Table 2.—Dimension stone sold or used by producers in the United States, by State

State	1977			1978			1979		
	Short tons	Cubic feet (thousands)	Value (thousands)	Short tons	Cubic feet (thousands)	Value (thousands)	Short tons	Cubic feet (thousands)	Value (thousands)
Alabama	13,992	171	$1,715	13,249	165	$1,739	12,352	158	$2,071
Alaska	85	1	1	--	--	--	--	--	--
Arizona	^{r}7,574	^{r}103	^{r}128	5,271	76	101	5,224	76	110
Arkansas	^{r}13,354	^{r}167	^{r}368	10,794	135	223	14,268	178	528
California	25,654	307	996	23,763	284	921	40,914	492	2,258
Colorado	4,896	62	181	4,648	59	178	3,295	42	163
Connecticut	9,101	108	240	8,686	102	240	13,040	156	475
Georgia	^{r}240,461	2,511	13,637	277,281	2,877	15,879	244,390	2,535	17,908
Hawaii	592	7	4	W	W	W	1,052	12	W
Illinois	2,545	30	109	2,600	31	122	3,000	35	128
Indiana	^{r}244,271	3,317	11,804	234,024	3,177	12,972	340,392	4,505	19,543
Iowa	W	W	W	9,934	147	480	10,197	120	508
Maryland	29,510	369	909	28,343	354	1,048	29,980	375	1,150
Massachusetts	62,619	753	4,856	68,227	820	6,411	48,118	579	4,389
Michigan	8,015	100	147	8146	101	155	8,977	112	166
Minnesota	33,376	395	8,133	34,843	416	9,356	38,446	458	11,543
Missouri	2,892	36	597	974	12	208	344	4	85
Montana	2,994	35	114	W	W	W	W	W	W
New Hampshire	72,996	^{r}260	4,650	60,875	702	4,077	85,563	1,005	5,774
New Mexico	17,500	240	106	18,012	247	115	20,184	277	117
New York	25,053	295	2,272	24,649	290	2,586	27,000	314	2,626
North Carolina	40,425	498	3,041	39,682	486	3,050	48,536	594	3,932
Ohio	^{r}147,492	1,915	3,557	89,712	1,211	3,295	49,750	681	1,702
Oklahoma	8,873	100	634	23,614	126	902	38,485	369	1,383
Oregon	W	W	W	W	W	W	265	3	4
Pennsylvania	65,879	794	5,362	69,932	841	5,215	76,646	714	5,961
South Carolina	13,162	145	627	10,501	120	567	8,586	98	482
South Dakota	34,900	396	11,404	36,309	408	11,859	35,500	403	13,268
Tennessee	13,409	162	941	12,215	147	1,035	11,988	144	1,000
Texas	27,298	358	3,922	28,269	349	4,192	17,074	214	3,636
Utah	6,073	78	238	6,527	84	264	4,953	64	216
Vermont	^{r}120,557	1,276	14,561	136,531	1,481	17,681	180,232	1,898	23,006

See footnotes at end of table.

Table 2.—Dimension stone sold or used by producers in the United States, by State —Continued

State	1977			1978			1979		
	Short tons	Cubic feet (thousands)	Value (thousands)	Short tons	Cubic feet (thousands)	Value (thousands)	Short tons	Cubic feet (thousands)	Value (thousands)
Virginia	9,931	113	$1,864	9,714	111	$1,943	8,530	97	$2,042
Washington	4,529	56	440	5,005	62	454	3,807	48	268
Wisconsin	73,141	889	4,821	63,676	773	4,562	54,317	665	4,204
Other States[1]	33,019	426	1,544	28,153	366	1,245	24,620	320	1,168
Total[2]	1,416,168	16,475	103,925	1,394,159	16,509	113,076	1,510,015	17,747	131,811
Puerto Rico	143,667	1,916	1,633	142,810	1,904	1,898	78,978	1,053	1,105

[r]Revised. W Withheld to avoid disclosing company proprietary data; included with "Other States."
[1]Includes Florida (1977), Idaho, Iowa, Kansas, New Jersey, Rhode Island, West Virginia, and Wyoming.
[2]Data may not add to totals shown because of independent rounding.

Table 3.—Crushed stone sold or used by producers in the United States, by State

(Thousand short tons and thousand dollars)

State	1977		1978		1979	
	Quantity	Value	Quantity	Value	Quantity	Value
Alabama	25,248	72,649	26,572	82,767	26,443	83,566
Alaska	4,008	17,493	3,487	14,649	3,656	15,458
Arizona	5,359	16,367	5,306	17,669	5,769	21,401
Arkansas	18,310	45,448	19,960	53,461	19,978	53,723
California	34,011	80,146	37,856	93,877	39,748	106,227
Colorado	5,597	14,169	6,229	15,683	6,835	19,435
Connecticut	6,980	20,319	7,364	22,801	8,271	38,767
Florida	48,558	[r]101,435	57,354	128,905	W	W
Georgia	37,864	[r]106,215	41,572	131,959	40,902	154,021
Hawaii	5,758	19,876	6,027	23,845	6,868	28,969
Idaho	3,077	8,005	2,624	6,670	2,952	8,788
Illinois	57,074	[r]135,964	62,453	160,352	63,551	188,130
Indiana	26,740	61,392	33,394	80,523	34,134	92,533
Iowa	29,183	76,964	31,310	88,618	32,471	103,215
Kansas	17,229	41,807	18,578	48,803	19,308	56,038
Kentucky	36,096	88,941	40,772	107,949	W	W
Louisiana	9,710	26,920	9,130	26,921	W	W
Maine	1,312	4,110	1,655	5,510	2,069	7,492
Maryland	16,736	49,772	19,427	66,263	21,561	80,550
Massachusetts	8,030	30,501	8,398	36,360	8,586	39,570
Michigan	40,517	84,971	40,129	90,981	39,809	99,832
Minnesota	7,831	16,991	9,666	20,734	9,751	22,175
Mississippi	2,176	3,933	2,409	5,176	W	W
Missouri	49,612	104,700	57,265	130,568	56,380	139,944
Montana	3,680	7,923	3,188	7,733	2,527	7,806
Nebraska	4,128	12,974	4,201	14,758	4,995	19,362
Nevada	1,668	5,506	1,426	5,489	1,602	6,439
New Hampshire	719	2,036	914	2,634	866	2,172
New Jersey	12,998	46,621	13,192	50,181	13,950	63,174
New Mexico	1,950	4,786	2,436	6,157	2,589	6,743
New York	29,922	88,509	35,748	98,530	36,901	112,362
North Carolina	32,810	87,254	37,687	108,867	39,864	125,319
Ohio	44,853	[r]116,409	49,316	130,472	50,717	149,819
Oklahoma	23,323	46,809	26,649	57,173	28,312	66,666
Oregon	17,600	39,400	17,685	39,509	25,738	65,074
Pennsylvania	63,522	[r]163,652	69,041	194,518	71,730	224,908
Rhode Island	274	1,236	300	1,316	249	1,148
South Carolina	14,772	36,043	16,997	44,237	16,589	48,352
South Dakota	3,377	7,477	3,693	8,376	3,891	10,317
Tennessee	41,897	99,196	45,460	117,271	45,718	133,727
Texas	65,446	[r]122,784	69,095	150,868	74,612	188,746
Utah	2,765	7,072	2,817	9,716	3,424	11,059
Vermont	2,123	12,635	1,971	13,179	2,077	13,927
Virginia	41,707	[r]109,737	50,442	141,601	51,080	165,223
Washington	12,239	28,156	9,789	22,059	15,192	35,788
West Virginia	10,495	28,022	11,582	32,897	11,713	37,624
Wisconsin	22,241	42,097	24,385	46,990	23,924	52,804
Wyoming	2,434	7,585	2,661	8,037	5,013	15,634
Other States	--	--	--	--	114,799	343,136
Total[1]	[r]953,955	[r]2,353,007	1,049,566	2,772,614	1,097,107	3,267,157
American Samoa	6	31	5	27	W	W
Guam	577	1,897	824	3,433	669	2,483
Puerto Rico	12,043	42,648	13,760	47,610	14,747	59,733
Virgin Islands	262	2,076	258	1,816	W	W

[r] Revised. W Withheld to avoid disclosing company proprietary data; included with "Other States."

[1] Data may not add to totals shown because of independent rounding.

Table 4.—Crushed stone sold or used by producers in the United States, by size of operation

(Thousand short tons)

Size range	1977			1978			1979		
	Number of operations	Quantity	Percent	Number of operations	Quantity	Percent	Number of operations	Quantity	Percent
0 to 25	[r]2,148	14,508	2	1,465	13,165	1	1,271	10,924	1
25 to 50	587	21,919	2	628	23,904	2	541	19,061	2
50 to 75	343	20,806	2	317	19,481	2	327	20,303	2
75 to 100	220	18,965	2	200	17,494	2	242	20,959	2
100 to 200	[r]618	87,898	9	548	80,084	8	544	79,682	7
200 to 300	375	91,129	10	357	86,995	8	340	83,821	8
300 to 400	[r]217	74,926	8	213	73,218	7	220	76,209	7
400 to 500	171	76,759	8	168	75,335	7	184	82,731	7
500 to 600	114	61,939	7	144	79,016	7	133	72,912	7
600 to 700	89	57,340	6	100	64,553	6	117	75,761	7
700 to 800	68	50,581	5	68	50,787	5	80	60,005	5
800 to 900	58	48,959	5	59	50,300	5	73	61,928	6
900 plus	197	328,227	34	252	415,233	40	258	432,811	39
Total[1]	[r]5,205	953,955	100	4,518	1,049,566	100	4,330	1,097,107	100

[r] Revised.
[1] Data may not add to totals shown because of independent rounding.

Table 5.—Crushed stone sold or used by producers in the United States, by method of transportation

(Thousand short tons)

Method	1977		1978		1979	
	Quantity	Percent	Quantity	Percent	Quantity	Percent
Truck	[r]771,034	81	853,351	81	900,707	82
Rail	82,264	8	87,486	9	86,201	8
Water	63,441	7	67,331	6	62,818	6
Other	37,216	4	41,397	4	47,381	4
Total[1]	[r]953,955	100	1,049,566	100	1,097,107	100

[r] Revised.
[1] Data may not add to totals shown because of independent rounding.

Table 6.—Dimension limestone sold or used by producers in the United States, by State

State	1977			1978			1979		
	Short tons	Cubic feet (thousands)	Value (thousands)	Short tons	Cubic feet (thousands)	Value (thousands)	Short tons	Cubic feet (thousands)	Value (thousands)
Alabama	W	W	W	W	W	W	7,880	105	$898
Alaska	85	1	$1	--	--	--	--	--	--
California	5,178	65	124	3,629	45	$96	5,443	68	142
Illinois	2,545	30	109	2,600	30	122	3,000	35	128
Indiana	[r]240,242	3,256	11,647	229,677	3,112	W	337,502	4,468	W
Iowa	W	W	W	9,934	147	480	10,197	120	508
Michigan	611	7	23	641	8	23	W	W	W
Minnesota	13,399	166	2,038	W	W	W	9,832	122	1,831
New York	234	4	4	--	--	--	--	--	--
Ohio	W	W	W	2,503	29	119	2,399	28	125
Texas	W	W	W	W	W	W	5,201	72	165
Virginia	835	10	53	847	10	W	W	W	W
Washington	1,712	21	61	1,778	22	66	W	W	59
Wisconsin	67,028	836	2,164	56,940	710	1,901	47,757	600	1,599
Other States[1]	[r]110,824	1,418	2,607	61,122	819	17,148	40,452	542	20,389
Total[2]	[r]442,693	5,816	18,832	369,671	4,933	19,955	469,663	6,161	25,845
Puerto Rico	[r]143,667	1,916	1,633	142,810	1,904	1,898	78,978	1,053	1,105

[r] Revised. W Withheld to avoid disclosing company proprietary data; included with "Other States."

[1] Includes Arizona (1977), Colorado, Florida (1977), Kansas, New Mexico, Oklahoma, and Rhode Island.

[2] Data may not add to totals shown because of independent rounding.

Table 7.—Crushed limestone sold or used by producers in the United States, by State

(Thousand short tons and thousand dollars)

State	1977		1978		1979	
	Quantity	Value	Quantity	Value	Quantity	Value
Alabama	23,341	58,190	24,875	65,971	24,597	68,264
Alaska	2,772	12,557	2,660	11,173	2,080	9,315
Arizona	4,633	13,671	4,395	14,619	4,903	17,660
Arkansas	7,013	19,256	7,446	22,017	7,955	20,261
California	17,239	39,641	17,739	43,818	19,156	54,872
Colorado	3,980	10,214	4,137	11,183	4,451	13,412
Connecticut	169	885	232	1,967	292	2,676
Florida	48,097	100,510	57,110	128,412	63,609	188,467
Georgia	4,478	11,162	5,511	15,737	6,442	27,540
Hawaii	1,097	3,800	1,274	4,440	1,429	5,606
Idaho	580	983	440	712	423	900
Illinois	57,074	[r]135,964	62,453	160,352	63,551	188,130
Indiana	26,724	61,366	33,378	80,505	34,121	92,513
Iowa	29,183	76,964	31,310	88,618	32,471	103,215
Kansas	16,761	40,325	18,078	46,695	18,853	53,552
Kentucky	36,068	88,782	40,743	107,769	39,298	116,641
Maine	881	2,509	1,131	3,274	1,135	3,643
Maryland	11,852	35,565	12,708	45,279	13,889	53,950
Massachusetts	709	8,289	766	9,912	W	W
Michigan	39,489	80,725	40,099	90,914	39,721	99,571
Minnesota	5,469	11,330	6,997	14,541	7,068	15,330
Mississippi	1,797	3,376	W	W	2,150	4,889
Missouri	47,708	[r]101,127	55,292	126,282	54,246	135,364
Montana	2,064	4,243	1,668	3,919	1,731	5,346
Nebraska	4,128	12,974	4,201	14,758	4,995	19,362
Nevada	1,499	5,137	1,402	5,436	1,278	5,514
New Mexico	1,441	3,684	1,578	4,397	1,677	4,543
New York	27,500	80,141	32,807	88,423	32,578	92,326
North Carolina	5,094	14,168	5,491	17,207	5,478	18,483
Ohio	43,355	[r]106,446	48,214	125,649	49,703	143,535
Oklahoma	22,787	45,359	25,932	55,088	27,649	64,599
Oregon	449	1,372	W	W	W	W
Pennsylvania	47,548	[r]123,409	52,694	149,500	56,122	176,161
South Carolina	3,604	8,698	W	W	W	W
South Dakota	2,276	4,249	2,584	4,702	2,789	6,640
Tennessee	41,893	99,053	45,456	117,128	45,714	133,584
Texas	61,369	[r]112,047	66,266	141,938	70,661	175,357
Utah	2,325	6,336	2,579	9,288	2,838	9,697
Vermont	1,067	10,090	1,318	11,356	1,484	12,129
Virginia	19,797	51,963	24,119	65,403	22,689	67,514
Washington	1,008	2,251	1,315	2,971	1,646	4,115
West Virginia	9,749	25,740	10,846	30,765	10,684	33,827
Wisconsin	18,160	32,718	18,745	35,552	20,625	43,251
Wyoming	1,588	4,378	1,819	4,635	3,241	9,021
Other States[1]	713	7,419	7,927	25,095	6,633	34,311
Total[2]	[r]706,521	[r]1,679,065	785,734	2,007,403	812,054	2,335,089
American Samoa	6	31	6	27	W	W
Guam	577	1,897	824	3,433	669	2,483
Puerto Rico	10,666	39,030	12,170	43,300	12,242	52,130

[r] Revised. W Withheld to avoid disclosing company proprietary data; included with "Other States."

[1] Includes New Jersey, Rhode Island, and States indicated by symbol W.

[2] Data may not add to totals shown because of independent rounding.

Table 8.—Dimension granite sold or used by producers in the United States, by State

State	1977 Short tons	1977 Cubic feet (thousands)	1977 Value (thousands)	1978 Short tons	1978 Cubic feet (thousands)	1978 Value (thousands)	1979 Short tons	1979 Cubic feet (thousands)	1979 Value (thousands)
California	3,356	41	[r]$356	2,639	32	$279	15,152	185	$1,552
Connecticut	4,906	55	155	4,436	49	154	4,667	49	222
Georgia	185,590	1,881	7,405	204,355	2,063	8,038	197,121	1,989	9,500
Massachusetts	62,619	753	4,856	W	W	W	46,618	564	4,249
Minnesota	18,514	211	6,071	21,640	249	6,989	26,820	313	9,680
Missouri	992	12	268	801	10	196	344	4	85
New Hampshire	72,996	[r]260	4,650	60,875	702	4,077	85,553	1,005	5,774
North Carolina	31,899	400	2,206	32,423	401	2,233	40,092	496	3,072
Oklahoma	W	W	W	W	W	670	28,981	346	1,246
Oregon	W	W	W	17	([1])	([1])	14	([1])	([1])
South Carolina	13,162	145	627	10,501	120	567	8,586	98	482
South Dakota	34,900	396	11,404	36,309	408	11,859	35,500	403	13,268
Texas	13,064	156	3,533	W	W	W	11,873	142	3,471
Vermont	82,623	857	8,771	W	W	W	111,295	1,138	12,740
Other States[2]	22,796	244	4,347	203,980	2,242	25,270	14,571	148	3,907
Total[3]	[r]547,417	[r]5,411	54,650	577,976	6,275	60,331	627,187	6,881	69,246

[r]Revised. W Withheld to avoid disclosing company proprietary data; included with "Other States."

[1] Less than 1/2 unit.

[2] Includes Colorado, New York, Pennsylvania, Virginia, Washington (1978 and 1979), and Wisconsin.

[3] Data may not add to totals shown because of independent rounding.

Table 9.—Crushed granite sold or used by producers in the United States, by State

(Thousand short tons and thousand dollars)

State	1977 Quantity	1977 Value	1978 Quantity	1978 Value	1979 Quantity	1979 Value
Alaska	1,164	4,703	713	3,322	940	3,885
Arizona	W	W	245	463	409	1,047
Arkansas	6,614	14,680	7,245	17,988	6,962	18,498
California	4,728	12,576	5,341	15,429	4,730	14,016
Colorado	1,173	2,702	1,747	3,526	2,105	4,812
Georgia	30,781	80,392	33,410	99,828	32,030	108,764
Idaho	1	2	W	W	W	W
Maine	W	W	--	--	30	30
Massachusetts	1,036	3,268	860	3,046	1,133	4,051
Minnesota	1,962	4,437	2,374	5,213	2,441	5,948
Montana	20	34	37	73	W	131
New Mexico	W	W	9	18	44	117
North Carolina	24,237	62,753	28,021	78,637	30,486	93,616
Oklahoma	--	--	W	127	W	W
Oregon	80	138	W	W	W	W
Pennsylvania	W	W	W	W	151	550
Rhode Island	W	W	260	W	145	W
South Carolina	9,752	25,336	10,924	30,358	10,595	33,285
South Dakota	77	77	77	77	W	W
Utah	60	119	51	101	--	--
Vermont	200	630	524	1,542	W	W
Virginia	14,929	37,937	18,285	50,362	18,845	62,380
Washington	1,599	2,878	W	W	153	413
Wisconsin	1,384	1,839	W	W	W	W
Wyoming	685	1,499	736	1,812	1,594	W
Other States[1]	8,074	20,414	10,929	26,115	9,541	34,086
Total[2]	[r]108,554	[r]276,413	121,789	338,038	122,335	385,628
Puerto Rico	W	W	W	W	W	W

[r]Revised. W Withheld to avoid disclosing company proprietary data; included with "Other States."

[1] Includes Connecticut, Maryland, Michigan (1979), Missouri, Nevada, New Hampshire, New Jersey, New York (1978 and 1979) and Texas.

[2] Data may not add to totals shown because of independent rounding.

Table 10.—Crushed traprock sold or used by producers in the United States, by State

(Thousand short tons and thousand dollars)

State	1977		1978		1979	
	Quantity	Value	Quantity	Value	Quantity	Value
Alaska	W	W	--	--	492	1,788
California	5,448	12,952	9,190	20,915	7,421	17,725
Colorado	307	808	W	W	83	245
Connecticut	6,471	18,303	6,850	19,436	7,856	35,331
Hawaii	W	W	W	W	5,393	23,191
Idaho	1,654	3,748	1,830	4,098	2,067	4,561
Maine	W	W	W	W	111	493
Maryland	2,251	7,106	W	W	3,770	13,032
Massachusetts	W	W	W	W	6,589	24,377
Michigan	W	W	4	7	W	W
Montana	1,190	2,640	1,017	2,400	410	1,332
Nevada	--	--	3	4	W	W
New Jersey	9,070	30,582	9,807	35,068	10,380	42,041
New Mexico	132	315	W	W	269	707
New York	1,440	5,184	2,000	7,257	3,516	17,410
North Carolina	2,949	8,735	3,690	11,637	3,578	12,058
Oregon	16,225	35,658	15,797	35,163	24,349	60,562
Pennsylvania	4,257	9,804	4,218	11,108	4,155	12,491
Texas	49	212	47	185	50	198
Virginia	4,746	11,632	5,917	17,049	6,718	23,382
Washington	8,649	19,265	7,582	17,043	12,388	28,654
Wisconsin	1,285	4,558	1476	5,355	1,162	5,206
Other States[1]	11,284	36,170	15,052	54,105	724	2,216
Total[2]	77,407	207,670	84,490	240,818	101,478	326,999
Puerto Rico	860	2,069	990	2,409	1,739	4,380
Virgin Islands	262	2,076	259	1,816	W	2,828

W Withheld to avoid disclosing company proprietary data; included with "Other States."

[1] Includes Arizona (1978), Minnesota, and New Hampshire.

[2] Data may not add to totals shown because of independent rounding.

Table 11.—Dimension sandstone sold or used by producers in the United States, by State

State	1977			1978			1979		
	Short tons	Cubic feet (thousands)	Value (thousands)	Short tons	Cubic feet (thousands)	Value (thousands)	Short tons	Cubic feet (thousands)	Value (thousands)
Arizona	3,079	50	$48	1,208	29	$29	1,128	28	$34
Arkansas	13,354	167	368	10,794	135	223	14,268	178	528
California	311	4	10	W	W	W	W	W	W
Colorado	4,353	56	115	4,189	54	116	2,855	37	91
Connecticut	4,195	53	85	4,250	54	86	8,373	107	253
Indiana	4,029	60	W	4,347	65	W	2,890	37	W
Maryland	16,118	201	561	20,448	256	777	20,692	259	775
Michigan	W	W	W	7,505	94	131	W	W	W
Minnesota	W	W	W	W	W	W	1,794	22	32
New York	16,555	198	1,371	16,114	193	1,522	19,658	231	1,726
Ohio	W	W	W	87,209	1,182	3,176	47,351	653	1,577
Oregon	--	--	--	26	(1)	1	15	(1)	(1)
Pennsylvania	35,004	449	956	40,640	521	1,212	42,717	344	1,381
Utah	W	W	W	6,527	84	264	4,953	64	216
Virginia	1,844	23	35	1,866	23	40	1,899	24	43
Washington	2,497	31	359	2,589	32	364	1,940	24	179
Wyoming	108	1	2	--	--	--	--	--	--
Other States[2]	[r]145,107	1,901	5,218	49,749	443	1,983	50,150	539	1,957
Total[3]	[r]246,554	3,195	9,129	257,461	3,165	9,925	220,683	2,547	8,794
Puerto Rico	--	--	--	--	--	--	--	--	--

[r] Revised. W Withheld to avoid disclosing company proprietary data; included with "Other States."

[1] Less than 1/2 unit.

[2] Includes Alabama, Georgia, Idaho (1978 and 1979), Montana, New Jersey, New Mexico (1977 and 1978), North Carolina, Oklahoma, (1978 and 1979), Tennessee, West Virginia, and Wisconsin.

[3] Data may not add to totals shown because of independent rounding.

Table 12.—Crushed sandstone sold or used by producers in the United States, by State

(Thousand short tons and thousand dollars)

State	1977		1978		1979	
	Quantity	Value	Quantity	Value	Quantity	Value
Arizona	542	1,833	478	1,676	394	1,837
Arkansas	4,572	9,878	5,157	11,822	4,916	12,835
California	2,600	5,406	2,022	4,547	4,625	10,058
Colorado	137	445	W	W	196	966
Georgia	1,875	5,503	1,978	6,426	1,654	5,898
Idaho	830	3,242	346	1,844	W	W
Kansas	468	1,481	500	2,109	454	2,486
Kentucky	27	159	29	180	W	W
Maryland	213	1,293	349	1,998	331	2,478
Montana	370	923	413	1,233	W	W
New Mexico	345	664	711	1,370	580	1,313
New York	973	3,126	799	2,555	708	2,297
North Carolina	197	800	65	124	W	W
Ohio	1,498	9,962	1,102	4,823	1,013	6,284
Oregon	634	1,848	621	1,639	574	2,453
Pennsylvania	6,024	17,265	5,890	19,292	5,331	20,419
South Dakota	1,024	3,151	1,031	3,598	1,025	3,600
Texas	1,316	3,774	830	4,038	1,938	6,804
Utah	--	--	156	263	210	588
Vermont	W	W	36	113	--	--
Virginia	1,411	4,088	1,269	4,132	1,482	5,760
Washington	532	2,298	559	1,415	705	1,971
West Virginia	746	2,281	735	2,132	1,028	3,798
Wisconsin	1,404	2,956	W	W	W	W
Other States[1]	2,456	8,830	3,186	8,973	4,023	14,777
Total[2]	30,187	91,210	28,262	86,295	31,188	106,621

W Withheld to avoid disclosing company proprietary data; included with "Other States."

[1] Includes Alabama (1977), Connecticut, Louisiana (1977 and 1978), Maine, Minnesota, Missouri, and Oklahoma (1978 and 1979).

[2] Data may not add to totals shown because of independent rounding.

Table 13.—Dimension marble sold or used by producers in the United States, by State

State	1977			1978			1979		
	Short tons	Cubic feet (thousands)	Value (thousands)	Short tons	Cubic feet (thousands)	Value (thousands)	Short tons	Cubic feet (thousands)	Value (thousands)
Arizona	W	W	W	W	W	$41	W	W	W
California	W	W	W	W	W	W	10,327	121	$339
Massachusetts	--	--	--	W	W	W	1,500	15	140
Texas	W	W	W	7,600	89	380	--	--	--
Other States[1]	96,654	1,113	$12,148	107,518	1,213	13,367	67,893	755	13,656
Total	96,654	1,113	12,148	115,118	1,302	13,788	79,720	891	14,135

W Withheld to avoid disclosing company proprietary data; included with "Other States."

[1] Includes Alabama, Georgia, Idaho, Missouri, Montana, New Mexico, North Carolina, Tennessee, Vermont, and Wyoming (1977 and 1978).

Table 14.—Crushed marble sold or used by producers in the United States, by State

(Thousand short tons and thousand dollars)

State	1977		1978		1979	
	Quantity	Value	Quantity	Value	Quantity	Value
Alabama	653	12,764	670	14,408	741	12,611
Arizona	40	532	W	W	63	857
California	--	--	8	254	7	212
Missouri	4	216	5	225	5	240
Nevada	--	--	([1])	2	([1])	2
Tennessee	W	W	W	W	4	143
Texas	W	W	54	775	59	838
Vermont	--	--	19	60	--	--
Other States[2]	843	10,435	661	9,423	583	10,182
Total[3]	1,540	23,947	1,417	25,146	1,461	25,085
Puerto Rico	W	W	W	W	W	W

W Withheld to avoid disclosing company proprietary data; included with "Other States."

[1] Less than 1/2 unit.

[2] Includes Georgia, North Carolina, Utah, Virginia (1977), Washington (1977), and Wyoming.

[3] Data may not add to totals shown because of independent rounding.

Table 15.—Crushed calcareous marl sold or used by producers in the United States, by State

(Thousand short tons and thousand dollars)

State	1977		1978		1979	
	Quantity	Value	Quantity	Value	Quantity	Value
Indiana	17	26	15	19	13	19
Michigan	22	67	26	59	23	56
North Carolina	213	478	321	1,019	260	957
South Carolina	1,416	2,009	W	W	W	W
Virginia	6	13	4	8	W	10
Other States[1]	843	1,148	2,219	3,256	2,355	3,497
Total[2]	2,517	3,740	2,585	4,360	2,650	4,538

W Withheld to avoid disclosing company proprietary data; included with "Other States."

[1] Includes Florida (1978), Maine, Mississippi, and Texas.

[2] Data may not add to totals shown because of independent rounding.

Table 16.—Crushed miscellaneous stone sold or used by producers in the United States, by State

(Thousand short tons and thousand dollars)

State	1977		1978		1979	
	Quantity	Value	Quantity	Value	Quantity	Value
Alaska	W	W	64	154	144	470
Arizona	40	154	22	76	--	--
California	3,976	9,148	3,537	8,263	3,789	8,959
Hawaii	W	W	W	W	46	172
Idaho	22	30	W	W	--	--
Maryland	429	1,149	499	1,352	433	1,264
Montana	35	83	52	106	--	--
New Mexico	W	W	W	W	20	W
Oregon	212	383	565	929	141	231
Pennsylvania	W	W	W	W	5,971	W
Rhode Island	11	38	W	W	W	W
Texas	--	--	37	56	--	--
Vermont	W	W	74	108	W	W
Virginia	W	W	W	W	487	1,264
Washington	W	W	W	W	290	631
Wisconsin	9	26	--	--	--	--
Wyoming	W	W	W	W	W	225
Other States[1]	8,109	18,796	7,040	17,271	1,149	19,912
Total[2]	12,843	29,806	11,891	28,317	12,479	33,128

W Withheld to avoid disclosing company proprietary data; included with "Other States."

[1] Includes Arkansas (1977 and 1978), Louisiana, Massachusetts, Nevada, New York (1977), North Carolina (1977), Oklahoma (1977), and Utah.

[2] Data may not add to totals shown because of independent rounding.

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Table 17.—Dimension stone sold or used by producers in the United States, by use

Use	1977			1978			1979		
	Short tons	Cubic feet (thousands)	Value (thousands)	Short tons	Cubic feet (thousands)	Value (thousands)	Short tons	Cubic feet (thousands)	Value (thousands)
Rough stone:									
Rough blocks	[r]234,752	3,037	$6,885	248,794	3,111	$7,598	347,959	4,257	$11,023
Irregular-shaped stone	153,456	1,853	4,116	139,152	1,510	3,933	129,667	1,471	4,275
Rubble	[r]179,927	2,252	2,360	128,312	1,622	2,080	99,296	1,249	1,807
Monumental	[r]271,844	2,903	16,820	273,880	2,806	19,370	268,124	2,779	21,583
Flagging	34,804	443	1,649	47,149	585	2,471	53,901	692	2,231
Other rough	[r]3,268	[r]41	[r]63	15,440	179	98	2,265	33	50
Dressed stone:									
Cut stone	[r]129,378	[r]1,435	21,908	141,795	1,823	25,040	152,858	1,743	29,695
Sawed stone	90,287	1,186	6,787	88,320	1,153	6,853	87,278	1,149	11,272
House stone veneer	[r]74,401	[r]934	[r]3,540	75,775	993	3,683	96,155	1,119	4,141
Construction	11,019	134	940	11,008	135	936	16,413	197	1,574
Monumental	56,175	599	21,371	57,469	650	23,174	53,153	604	21,216
Curbing	[r]103,192	[r]926	7,487	94,706	1,124	7,695	98,311	1,177	7,621
Flagging	33,789	388	1,669	26,395	305	1,493	53,897	693	2,597
Roofing slate	9,934	109	2,338	8,326	92	2,302	9,520	105	3,114
Structural shapes	11,629	128	3,298	8,261	91	2,991	8,885	98	3,763
Blackboards	134	1	107	215	2	51	146	2	58
Billiard table tops	2,000	23	451	844	9	238	W	W	W
Flooring slate	6,349	70	955	11,574	127	1,494	22,956	253	4,082
Other uses[1]	[r]9,770	[r]113	[r]1,230	16,744	192	1,625	19,231	218	1,709
Total[2]	[r]1,416,168	[r]16,475	[r]103,925	1,394,159	16,509	113,076	1,510,015	17,747	131,811

[r] Revised. W Withheld to avoid disclosing company proprietary data; included with "Other uses."

[1] Includes electrical fixtures and paving blocks.

[2] Data may not add to totals shown because of independent rounding.

Table 18.—Crushed stone sold or used by producers in the United States, by use

(Thousand short tons and thousand dollars)

Use	1977		1978		1979	
	Quantity	Value	Quantity	Value	Quantity	Value
Agricultural limestone	31,966	96,679	33,429	105,126	32,902	116,457
Agricultural marl and other soil conditioners	559	1,903	675	2,501	691	3,118
Poultry grit and mineral food	2,369	12,800	2,742	17,606	2,906	21,110
Concrete aggregate (coarse)	r124,514	r322,372	137,102	377,097	141,510	443,352
Bituminous aggregate	93,864	r252,675	99,648	287,423	99,564	321,411
Macadam aggregate	25,307	56,364	28,337	68,720	26,000	71,433
Dense-graded roadbase stone	r220,591	r494,148	249,894	596,036	254,261	676,057
Surface treatment aggregate	44,920	r111,632	51,115	140,557	55,456	170,668
Other construction aggregate and roadstone	156,250	r367,374	174,376	437,608	204,780	586,616
Riprap and jetty stone	21,114	50,339	21,672	58,518	24,711	69,280
Railroad ballast	25,484	57,447	27,506	67,262	30,439	85,305
Filter stone	2,079	5,515	3,051	8,677	3,796	11,690
Manufactured fine aggregate (stone sand)	11,801	32,611	16,576	46,712	19,490	66,585
Terrazzo and exposed aggregate	625	7,846	745	9,487	1,211	14,921
Cement manufacture	r103,889	r190,255	108,246	208,596	109,268	232,907
Lime manufacture	r31,016	r75,302	32,982	88,213	34,702	99,556
Dead burned dolomite	1,823	3,783	1,801	4,067	1,779	4,903
Ferrosilicon	339	1,402	390	1,776	466	2,344
Flux stone	23,067	59,049	24,281	68,794	22,881	71,026
Refractory stone (include ganister)	844	5,679	1,066	6,495	488	6,172
Chemical stone for alkali works	2,352	6,346	2,201	6,443	1,966	6,409
Abrasives	157	1,048	185	996	214	1,243
Mine dusting	1,237	8,463	1,259	7,769	1,268	10,278
Asphalt filler	1,131	5,234	1,058	5,600	1,250	6,012
Whiting or whiting substitute	833	21,711	1,062	27,586	1,361	32,587
Other fillers or extenders	3,012	36,227	3,641	40,716	3,755	49,250
Acid neutralization	295	1,071	277	977	W	W
Building materials	62	131	191	436	130	354
Chemicals	615	1,048	36	130	41	152
Bedding materials	61	238	41	192	34	178
Dam construction	--	--	--	--	45	89
Drain fields	30	63	34	74	65	179
Fill	4,608	6,649	4,269	6,403	3,004	5,567
Slate flour	W	W	W	W	70	857
Glass manufacture	2,698	16,683	2,131	14,264	2,190	14,727
Lightweight aggregate	492	5,404	537	6,452	590	7,635
Paper manufacture	116	r411	109	356	128	446
Porcelain	W	W	69	152	W	W
Roofing granules	5,099	14,702	6,070	18,762	5,264	18,221
Sugar refining	1,172	3,634	924	3,552	1,367	6,507
Waste materials	W	W	274	321	39	76
Sulfur removal from stack gases	807	1,962	723	1,897	967	2,942
Other uses not specified[1]	r6,639	17,727	8,839	26,273	6,469	18,540
Total[2]	r953,955	r2,353,007	1,049,566	2,772,614	1,097,107	3,267,157

rRevised. W Withheld to avoid disclosing company proprietary data; included with "Other uses."

[1] Includes disinfectant and animal sanitation, magnesium metal manufacture, and other uses.

[2] Data may not add to totals shown because of independent rounding.

Table 19.—Dimension limestone sold or used by producers in the United States, by use

Use	1977			1978			1979		
	Short tons	Cubic feet (thousands)	Value (thousands)	Short tons	Cubic feet (thousands)	Value (thousands)	Short tons	Cubic feet (thousands)	Value (thousands)
Rough stone:									
Rough blocks	r148,157	2,001	$4,215	134,010	1,796	$4,068	207,843	2,672	$6,276
Irregular-shaped stone	29,489	367	435	6,720	86	178	5,785	74	172
Rubble	99,685	1,252	1,090	54,154	710	775	48,939	573	647
Flagging	15,371	201	338	15,168	199	320	26,645	357	414
Other rough stone	W	W	W	54	1	1	45	1	1
Dressed stone:									
Cut stone	49,851	668	7,342	58,490	799	9,082	55,884	754	10,866
Sawed stone	38,629	527	2,672	38,811	524	2,578	55,860	766	3,982
House stone veneer	53,787	703	2,445	55,921	736	2,649	64,569	853	3,063
Construction	3,926	49	99	3,329	42	149	5,823	69	223
Curbing	W	W	W	W	W	W	311	4	15
Flagging	2,900	37	132	2,527	33	120	2,679	35	117
Other uses[1]	898	12	64	487	6	35	280	4	118
Total[2]	r442,693	5,816	18,832	369,671	4,933	19,955	469,663	6,161	25,845

rRevised. W Withheld to avoid disclosing company proprietary data; included with "Other uses."

[1] Includes other rough stone (1977) and dressed curbing (1977-78).

[2] Data may not add to totals shown because of independent rounding.

Table 20.—Crushed limestone sold or used by producers in the United States, by use

(Thousand short tons and thousand dollars)

Use	1977		1978		1979	
	Quantity	Value	Quantity	Value	Quanity	Value
Agricultural limestone	31,863	95,282	33,429	106,126	32,902	116,457
Agricultural marl and other soil conditioners	361	1,435	374	1,425	436	2,136
Poultry grit and mineral food	1,958	11,749	2,224	15,986	2,442	19,567
Concrete aggregate	97,465	245,494	110,826	294,067	113,407	342,599
Bituminous aggregate	60,205	156,088	65,814	186,717	66,788	212,707
Macadam aggregate	21,819	47,218	25,266	59,196	22,646	59,884
Dense-graded roadbase stone	[r]151,468	319,045	164,837	369,390	169,281	422,723
Surface treatment aggregate	35,945	89,244	39,872	108,461	38,517	122,515
Other construction aggregate and roadstone	98,965	226,361	120,897	298,576	134,839	371,024
Riprap and jetty stone	13,450	31,597	12,939	34,467	16,229	43,028
Railroad ballast	10,825	24,037	11,912	28,452	14,035	37,635
Filter stone	1,365	3,348	1,844	5,045	2,689	7,911
Manufactured fine aggregate (stone sand)	8,990	23,867	12,492	34,966	15,609	51,371
Terrazzo and exposed aggregate	349	3,119	454	4,668	624	7,531
Cement manufacture	99,049	181,440	103,382	198,757	104,908	228,603
Lime manufacture	30,214	74,041	32,209	86,580	34,054	98,042
Dead-burned dolomite	1,823	3,783	1,801	4,067	1,779	4,903
Flux stone	21,628	53,024	23,407	64,909	21,271	64,945
Refractory stone	35	80	483	2,045	20	64
Chemical stone for alkali works	2,352	6,346	2,201	6,443	1,966	6,409
Abrasives	60	360	146	713	141	656
Mine dusting	1,337	8,463	1,259	7,769	1,267	10,379
Asphalt filler	851	4,166	829	4,526	1,007	5,425
Whiting or whiting substitute	696	17,120	856	21,874	1,085	29,970
Other filler or extenders	1,987	20,043	2,701	25,317	2,792	31,691
Acid neutralization	295	1,071	277	977	W	W
Building products	29	66	145	339	129	350
Other chemicals	615	1,048	36	130	41	152
Bedding materials	16	37	10	14	--	--
Dam construction	--	--	--	--	22	44
Drain fields	28	58	20	38	W	W
Fill	2,503	3,059	2,883	4,194	2,127	4,090
Glass manufacture	1,783	10,580	2,100	14,116	2,146	14,507
Paper manufacture	116	411	109	356	128	446
Roofing granules	300	1,489	399	2,154	376	2,307
Sugar refining	1,172	3,634	924	3,552	1,367	5,968
Waste material	274	321	274	321	39	76
Sulfur removal from stack gases	807	1,962	723	1,897	967	2,942
Other uses[1]	3,523	8,581	5,382	14,885	3,977	11,038
Total[2]	[r]706,521	[r]1,679,065	785,784	2,007,403	812,054	2,335,089

[r] Revised. W Withheld to avoid disclosing company proprietary data; included with "Other uses."

[1] Includes ferrosilicon, disinfectant and animal sanitation, magnesium metal manufacture, porcelain, stucco (1977), and other uses.

[2] Data may not add to totals shown because of independent rounding.

Table 21.—Crushed limestone sold or used by producers in the United States, by State and use

(Thousand short tons and thousand dollars)

State	Aggregates		Cement		Aglime		Lime		Flux stone		Riprap		Railroad ballast		Other uses		Total[2]	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1978																		
Alabama	13,494	33,264	4,712	9,378	1,410	5,330	1,931	9,366	1,677	4,014	644	1,927	W	W	1,007	2,692	24,875	65,971
Alaska	2,660	11,173	--	--	--	--	--	--	--	--	(1)	(1)	--	--	--	--	2,660	11,173
Arizona	194	686	W	W	--	--	818	3,678	324	1,168	7	41	W	W	3,052	9,051	4,395	14,619
Arkansas	3,654	13,427	W	W	450	1,322	W	W	W	W	80	187	W	282	3,262	6,799	7,446	22,017
California	3,468	5,987	12,168	23,509	W	W	562	1,816	56	178	2	11	--	--	1,483	12,317	17,739	43,818
Colorado	W	W	W	W	W	W	W	W	W	W	W	W	--	--	4,137	11,180	4,137	11,183
Connecticut	W	W	--	--	W	W	--	--	W	W	--	--	--	--	232	1,967	232	1,967
Florida	49,645	112,437	2,731	3,455	1,000	3,695	W	W	--	--	51	265	W	W	3,683	8,560	57,110	128,412
Georgia	3,435	10,069	W	W	193	604	--	--	--	--	40	120	W	W	1,843	4,944	5,511	15,737
Hawaii	336	2,065	894	2,155	30	125	W	W	--	--	--	--	--	--	14	75	1,274	4,440
Idaho	W	W	W	W	--	--	--	--	--	--	(1)	(1)	--	--	440	712	440	712
Illinois	50,172	124,276	3,189	6,191	4,844	13,530	W	W	W	W	600	1,584	800	1,675	2,848	13,097	62,453	160,353
Indiana	26,678	65,151	3,114	5,319	2,405	6,052	--	--	W	W	304	851	314	732	563	2,410	33,378	80,505
Iowa	22,206	64,873	3,751	6,291	2,870	8,662	W	W	W	W	246	877	1,026	2,533	1,209	5,382	31,310	88,618
Kansas	13,316	36,597	3,526	6,950	576	1,335	--	--	--	--	203	632	87	241	370	940	18,078	46,695
Kentucky	32,414	86,540	907	1,510	2,133	6,105	1,365	2,790	70	210	3,086	7,532	111	297	657	2,785	40,743	107,769
Maine	390	1,331	W	W	W	W	--	--	--	--	7	25	W	W	734	1,917	1,131	3,274
Maryland	9,637	30,255	2,351	3,519	W	W	24	74	--	--	138	595	121	238	437	10,598	12,708	45,279
Massachusetts	W	W	--	--	150	1,157	W	W	5	46	(1)	(1)	--	--	611	8,707	766	9,912
Michigan	10,571	23,436	6,997	12,850	512	1,164	9,389	21,543	10,660	27,497	174	363	292	651	1,504	3,410	40,099	90,914
Minnesota	5,696	11,491	--	--	555	1,346	--	--	--	--	76	162	W	W	670	1,542	6,997	14,541
Mississippi	W	W	W	W	659	1,969	--	--	--	--	W	W	W	W	W	W	W	W
Missouri	37,468	88,033	6,044	11,009	4,174	10,464	3,200	5,608	W	W	2,917	6,288	62	151	1,427	4,728	55,292	126,282
Montana	51	119	W	W	--	--	312	777	42	W	14	27	--	--	1,249	2,996	1,668	3,919

Nebraska	2,740	9,713	W	W	157	478	--	--	--	--	209	907	W	W	1,096	3,660	4,201	14,758
Nevada	32	45	W	W	--	--	W	W	W	W	1	3	--	--	1,369	5,388	1,402	5,436
New Jersey	W	W	--	--	W	W	18	56	W	W	--	--	--	--	W	W	W	W
New Mexico	766	1,775	W	W	--	--	123	W	14	W	W	W	W	W	675	2,622	1,578	4,397
New York	24,325	68,603	5,605	9,744	389	1,665	W	W	W	W	667	2,109	313	807	1,508	5,495	32,807	88,423
North Carolina	4,222	13,463	W	W	22	83	--	--	--	--	W	W	W	W	1,247	3,661	5,491	17,207
Ohio	32,442	80,276	3,189	9,389	1,847	6,021	2,831	6,235	3,776	9,169	751	2,472	1,164	2,527	2,214	9,560	48,214	125,649
Oklahoma	19,897	41,932	2,551	3,885	439	870	W	W	--	--	381	920	1,794	4,112	870	3,372	25,932	55,068
Oregon	W	W	W	W	W	W	--	--	--	--	--	--	W	W	W	W	W	W
Pennsylvania	32,138	84,283	9,052	19,015	1,497	8,282	3,217	10,427	2,766	11,075	394	1,212	1,141	3,208	2,469	11,998	52,604	149,500
Rhode Island	--	--	--	--	W	W	--	--	W	W	--	--	--	--	W	W	W	W
South Carolina	2,583	6,880	1,465	W	478	2,486	--	--	--	--	W	W	W	W	W	W	W	W
South Dakota	1,347	2,828	756	1,005	W	W	302	528	--	--	--	--	W	W	180	340	2,584	4,702
Tennessee	38,231	96,013	2,133	5,365	2,600	7,369	78	156	--	--	525	1,217	207	435	1,682	6,573	45,456	117,128
Texas	50,896	111,642	8,706	12,320	870	1,267	2,727	5,778	411	733	430	1,256	849	2,192	1,377	6,750	66,266	141,938
Utah	W	W	905	2,775	--	--	W	W	W	W	W	W	W	W	1,584	6,518	2,579	9,288
Vermont	659	1,727	--	--	W	W	--	--	--	--	22	64	99	361	538	9,204	1,318	11,356
Virginia	17,350	45,767	1,609	2,588	1,620	7,612	1,723	4,042	222	488	56	164	67	170	1,472	4,572	24,119	65,403
Washington	W	W	W	W	W	W	W	W	--	--	W	W	--	--	1,315	2,971	1,315	2,971
West Virginia	7,428	22,397	W	W	106	401	W	W	W	W	55	195	649	1,299	2,608	6,473	10,846	30,765
Wisconsin	17,232	31,151	--	--	969	2,585	W	W	15	25	217	1,001	W	W	312	790	18,745	35,552
Wyoming	658	987	W	W	--	--	--	--	--	--	50	W	778	W	333	3,648	1,819	4,636
Total (excluding withheld)	538,427	1,340,712	86,445	158,222	32,955	101,979	28,619	72,869	20,038	54,603	12,347	33,006	9,874	21,911	54,306	210,399	777,809	1,982,306
Withheld	1,576	5,602	16,940	40,534	475	3,146	3,589	13,660	3,368	10,306	592	1,459	2,039	6,543	2,724	13,704	7,927	25,095
U.S. total[3]	540,003	1,346,312	103,382	198,757	33,429	105,126	32,209	86,530	23,407	64,909	12,939	34,467	11,912	28,452	28,453	142,850	785,734	2,007,408

See footnotes at end of table.

Table 21.—Crushed limestone sold or used by producers in the United States, by State and use —Continued

(Thousand short tons and thousand dollars)

State	Aggregates		Cement		Aglime		Lime		Flux stone		Riprap		Railroad ballast		Other uses		Total[3]	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1978 —Continued																		
American Samoa	6	27	--	--	--	--	--	--	--	--	--	--	--	--	--	--	6	27
Guam	W	2,515	--	--	--	--	--	--	--	--	50	319	--	--	W	82	W	2,916
Puerto Rico	9,219	38,350	W	W	--	--	W	W	--	--	--	--	--	--	2,950	4,958	12,169	43,312
1979																		
Alabama	11,918	32,046	4,462	9,858	1,873	5,942	2,848	10,415	1,943	5,463	924	2,855	189	517	440	1,174	24,597	68,264
Alaska	2,034	9,108	--	--	28	142	--	--	--	--	--	--	--	--	17	70	2,080	9,315
Arizona	125	347	W	W	--	--	1,265	5,935	317	1,081	27	84	W	W	3,170	10,213	4,903	17,660
Arkansas	4,215	10,878	W	W	400	1,267	W	W	W	W	138	523	321	808	2,881	6,786	7,955	20,261
California	3,275	7,593	13,135	28,439	24	110	744	2,610	99	437	99	248	--	--	1,779	15,435	19,156	54,872
Colorado	480	1,095	3,025	8,570	2	5	23	69	648	2,322	17	40	--	--	307	1,311	4,451	13,412
Connecticut	W	W	14	24	65	409	20	35	W	W	--	--	--	--	194	2,208	292	2,676
Florida	57,193	167,730	2,344	5,139	1,131	6,036	367	1,007	--	--	58	277	W	W	2,516	8,278	63,600	188,467
Georgia	3,853	12,074	W	W	453	2,219	--	--	--	--	40	129	W	W	2,096	13,117	6,442	27,540
Hawaii	469	2,981	985	2,490	W	W	--	--	--	--	--	--	--	--	24	135	1,429	5,606
Idaho	1	2	W	W	--	--	--	--	--	--	--	--	--	--	422	897	423	900
Illinois	50,886	146,324	3,280	6,836	5,241	16,445	W	W	862	2,547	534	1,583	509	1,411	2,240	12,984	63,551	188,130
Indiana	26,967	73,954	3,388	6,206	2,198	6,727	--	--	W	W	314	1,019	648	1,755	606	2,852	34,121	92,513
Iowa	23,629	76,979	3,362	5,990	2,806	9,469	W	W	W	W	368	1,341	1,071	2,801	1,240	6,634	32,471	103,215
Kansas	14,036	42,881	3,640	7,454	767	1,999	W	3	--	--	108	396	47	182	255	637	18,853	53,552
Kentucky	31,488	93,687	W	W	1,675	5,346	W	W	66	218	2,744	7,297	280	750	3,046	9,343	39,298	116,641
Maine	395	1,441	W	W	W	W	--	--	--	--	4	22	39	153	696	2,027	1,135	3,643
Maryland	10,637	34,823	2,477	3,934	W	W	28	74	--	--	176	752	90	215	485	14,153	13,889	53,950
Massachusetts	--	--	--	--	W	W	W	W	6	55	(1)	1	--	--	W	W	W	W
Michigan	13,003	32,159	7,284	15,159	366	956	9,810	25,027	7,468	21,489	588	1,607	437	1,075	815	2,099	39,721	99,571
Minnesota	5,963	12,591	--	--	383	959	--	--	--	--	71	219	W	W	651	1,562	7,068	15,330
Mississippi	384	918	W	W	730	2,207	--	--	--	--	161	425	W	W	875	1,344	2,150	4,889
Missouri	34,210	91,056	6,043	11,923	4,401	11,879	3,230	6,116	W	W	4,843	8,681	56	99	1,464	5,609	54,246	135,364
Montana	281	677	W	W	--	--	319	833	70	W	(1)	(1)	--	--	1,111	3,836	1,731	5,346

Nebraska	3,234	12,989	W	W	167	589	--	--	4	17	189	871	W	W	1,401	4,897	4,995	19,362
Nevada	--	--	W	W	--	--	W	W	W	W	2	8	--	--	1,276	5,506	1,278	5,514
New Mexico	941	2,218	W	W	--	--	127	W	15	W	59	127	W	W	535	2,198	1,677	4,543
New York	23,171	69,748	6,204	10,888	370	1,813	W	W	W	W	656	2,248	415	1,105	1,761	6,525	32,578	92,326
North Carolina	4,190	14,336	W	W	W	W	--	--	--	--	W	W	W	W	1,288	4,147	5,478	18,483
Ohio	33,761	93,823	3,407	11,505	1,647	6,038	3,604	8,588	3,631	9,649	474	1,394	1,163	2,769	2,015	9,770	49,703	143,535
Oklahoma	21,705	50,442	2,303	4,275	467	942	W	W	--	--	616	1,324	2,011	5,174	547	2,442	27,649	64,599
Pennsylvania	34,842	104,505	9,374	20,252	1,728	10,028	3,259	10,854	2,955	12,199	506	1,762	1,347	4,198	2,112	12,364	56,122	176,161
Rhode Island	54	135	--	--	W	W	--	--	W	W	--	--	--	--	W	W	W	W
South Carolina	2,819	8,363	1,333	W	347	1,936	--	--	--	--	W	W	W	W	W	W	W	W
South Dakota	1,412	4,259	W	W	--	--	310	589	--	--	--	--	W	W	1,066	1,791	2,789	6,640
Tennessee	38,885	110,964	1,619	4,572	2,068	5,767	W	W	--	--	855	2,517	237	581	2,051	9,184	45,714	133,584
Texas	55,139	139,767	9,090	14,619	310	620	2,101	4,814	987	2,080	255	931	855	2,682	1,923	9,844	70,661	175,357
Utah	W	W	1,066	3,408	--	--	W	W	W	W	W	W	W	W	1,772	6,289	2,838	9,697
Vermont	946	2,668	--	--	W	W	--	--	--	--	W	W	W	W	538	9,461	1,484	12,129
Virginia	15,783	45,956	1,649	2,752	1,710	8,361	1,607	3,917	201	504	67	219	25	58	1,646	5,747	22,689	67,514
Washington	176	531	W	W	8	107	--	--	--	--	W	W	--	--	1,462	3,477	1,646	4,115
West Virginia	7,852	25,961	W	W	83	348	W	W	W	W	63	245	650	1,289	2,037	5,963	10,684	33,827
Wisconsin	18,957	37,462	--	--	929	2,870	W	W	13	26	460	2,153	W	W	258	742	20,625	43,251
Wyoming	1,300	3,052	W	W	--	--	--	--	--	--	68	W	1424	W	449	5,968	3,241	9,021
Total (excluding withheld)	560,509	1,578,513	89,384	184,288	32,377	111,536	29,657	80,886	19,285	58,087	15,488	41,298	11,814	27,622	51,467	229,039	805,422	2,300,775
Withheld[2]	578	4,310	15,523	39,317	528	4,921	4,398	17,157	1,987	6,858	741	1,732	2,219	10,013	2,074	23,822	6,633	34,311
U.S. total[3]	561,087	1,582,821	104,908	223,603	32,902	116,457	34,054	98,042	21,271	64,945	16,229	43,028	14,035	37,635	27,566	168,558	812,054	2,335,089

See footnotes at end of table.

Table 21.—Crushed limestone sold or used by producers in the United States, by State and use —Continued

(Thousand short tons and thousand dollars)

State	Aggregates		Cement		Aglime		Lime		Flux stone		Riprap		Railroad ballast		Other uses		Total[3]	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1979 —Continued																		
American Samoa	W	W	--	--	--	--	--	--	--	--	--	--	--	--	--	--	W	W
Guam	620	2,239	--	--	--	--	--	--	--	--	37	187	--	--	11	56	669	2,483
Puerto Rico	9,308	46,350	W	W	49	106	W	W	--	--	--	--	--	--	2,284	5,674	12,242	52,130

W Withheld to avoid disclosing company proprietary data; included with "Total withheld" and with "Other uses."

[1] Less than 1/2 unit.

[2] Includes New Jersey, Oregon, and states indicated by symbol W.

[3] Data may not add to totals shown because of independent rounding.

Table 22.—Dimension granite sold or used by producers in the United States, by use

Use	1977			1978			1979		
	Short tons	Cubic feet (thousands)	Value (thousands)	Short tons	Cubic feet (thousands)	Value (thousands)	Short tons	Cubic feet (thousands)	Value (thousands)
Rough stone:									
Rough blocks	33,131	347	$1,419	63,328	649	$2,310	95,140	998	$3,600
Irregular-shaped stone	10,094	114	329	11,100	126	379	13,328	145	485
Rubble	23,444	267	219	26,370	297	298	18,017	209	238
Monumental	^{r}270,731	2,791	16,748	272,767	2,794	19,297	267,011	2,767	21,511
Other rough stone	^{r}258	3	^{r}6	307	3	9	234	2	14
Dressed stone:									
Cut stone	48,037	^{r}368	10,885	46,869	566	11,647	59,132	716	13,918
Sawed stone	3,106	37	124	3,384	40	128	4,030	48	181
House stone veneer	3,970	^{r}11	130	4,612	55	173	4,932	60	167
Construction	6,168	74	800	5,351	65	672	5,126	64	690
Monumental	42,623	443	16,154	42,386	476	17,039	50,147	571	19,864
Curbing	^{r}102,804	^{r}921	7,465	93,891	1,114	7,637	97,673	1,169	7,572
Flagging	^{r}60	^{r}1	^{r}3	W	W	W	W	W	W
Other uses[1]	^{r}2,991	36	^{r}368	7,611	90	748	12,417	133	1,007
Total[2]	^{r}547,417	^{r}5,411	54,650	577,976	6,275	60,331	627,187	6,881	69,246

^{r}Revised. W Withheld to avoid disclosing company proprietary data; included with "Other uses."

[1] Includes paving blocks, rough flagging, and uses indicated by symbol W.

[2] Data may not add to totals shown because of independent rounding.

Table 23.—Crushed granite sold or used by producers in the United States, by use

(Thousand short tons and thousand dollars)

Use	1977		1978		1979	
	Quantity	Value	Quantity	Value	Quantity	Value
Poultry grit and mineral food	25	298	24	293	25	248
Concrete aggregate	18,427	50,913	16,418	50,169	15,834	53,875
Bituminous aggregate	17,048	46,596	17,414	47,379	14,644	50,037
Macadam aggregate	1,682	4,212	1,612	5,217	1,205	4,432
Dense-graded roadbase stone	33,842	84,699	43,185	118,491	37,642	113,654
Surface treatment aggregate	3,168	8,215	6,468	19,402	7,596	24,742
Other construction aggregate and roadstone	15,859	39,935	16,420	43,804	25,890	83,249
Riprap and jetty stone	2,163	5,220	2,246	6,836	2,436	7,928
Railroad ballast	9,653	20,888	10,663	25,320	11,564	30,581
Filter stone	99	301	536	1,628	405	1,424
Manufactured fine aggregate (stone sand)	1,306	3,069	2,087	5,325	1,820	5,484
Terrazzo and exposed aggregate	58	439	90	571	61	480
Asphalt filler	W	W	W	W	143	671
Fill	824	1,164	218	321	244	445
Roofing granules	1,973	3,773	2,165	5,476	1,764	4,717
Other uses[1]	^{r}2,427	6,689	2,243	7,807	1,061	3,659
Total[2]	^{r}108,554	^{r}276,413	121,789	338,038	122,335	385,628

^{r}Revised. W Withheld to avoid disclosing company proprietary data; included with "Other uses."

[1] Includes bedding material, and uses not specified.

[2] Data may not add to totals shown because of independent rounding.

Table 24.—Crushed traprock sold or used by producers in the United States, by use

(Thousand short tons and thousand dollars)

Use	1977		1978		1979	
	Quantity	Value	Quantity	Value	Quantity	Value
Concrete aggregate	5,211	16,020	6,655	21,849	9,145	34,569
Bituminous aggregate	11,518	34,856	12,604	40,543	12,791	50,572
Macadam aggregate	1,542	4,380	991	2,826	1,864	5,889
Dense-graded roadbase stone	17,515	43,808	26,740	67,709	31,539	93,600
Surface treatment aggregate	4,286	10,232	3,323	8,605	7,231	16,617
Other construction aggregate and roadstone	26,997	68,996	22,052	63,158	27,351	85,976
Riprap and jetty stone	3,167	8,392	4,134	11,096	4,015	11,820
Railroad ballast	3,355	8,422	3,514	9,920	3,642	13,554
Filter stone	327	1,016	335	865	345	989
Manufactured fine aggregate (stone sand)	758	3,051	920	4,413	967	5,194
Terrazzo and exposed aggregate	W	W	1	5	7	76
Bedding material	21	93	W	W	W	W
Fill	391	802	277	537	165	327
Roofing granules	1,928	5,758	2,557	7,222	2,131	6,705
Other uses[1]	387	1,842	389	2,069	296	1,112
Total[2]	77,407	207,670	84,490	240,818	101,478	326,999

W Withheld to avoid disclosing company proprietary data; included with "Other uses."

[1] Includes asphalt fillers, other fillers (1978-79), drain fields, and building products.

[2] Data may not add to totals shown because of independent rounding.

Table 25.—Dimension sandstone sold or used by producers in the United States, by use

Use	1977			1978			1979		
	Short tons	Cubic feet (thousands)	Value (thousands)	Short tons	Cubic feet (thousands)	Value (thousands)	Short tons	Cubic feet (thousands)	Value (thousands)
Rough stone:									
Rough blocks	35,677	465	$619	[r]34,566	471	$637	37,475	504	$730
Irregular-shaped stone	58,087	713	1,315	[r]75,729	775	1,663	63,512	718	1,526
Rubble	45,632	602	771	[r]38,245	502	741	28,053	355	655
Flagging	17,715	222	1,230	[r]21,457	267	1,542	24,667	305	1,741
Other rough	2,383	30	49	1,649	[r]26	27	1,985	30	35
Dressed stone:									
Cut stone	24,816	321	2,116	[r]29,568	381	2,528	33,480	224	2,380
Sawed stone	39,908	526	1,891	[r]36,188	478	1,855	10,607	144	607
House stone veneer	14,876	200	572	[r]13,482	182	534	9,457	122	415
Construction	--	--	--	--	--	--	1,645	21	38
Flagging	6,787	85	336	5,982	74	323	8,361	104	452
Other uses[1]	723	9	228	647	9	74	1,441	18	215
Total[2]	[r]246,554	3,195	9,129	257,461	3,165	9,925	220,683	2,547	8,794

[r] Revised.

[1] Includes curbing.

[2] Data may not add to totals shown because of independent rounding.

Table 26.—Crushed sandstone sold or used by producers in the United States, by use

(Thousand short tons and thousand dollars)

Use	1977		1978		1979	
	Quantity	Value	Quantity	Value	Quantity	Value
Concrete aggregate	2,620	8,263	2,800	9,955	2,772	11,145
Bituminous aggregate	3,952	11,616	3,168	10,859	4,749	16,263
Macadam aggregate	W	W	26	84	W	W
Dense-graded roadbase stone	7,017	16,763	6,932	18,108	6,892	19,159
Surface treatment aggregate	1,237	3,255	1,059	3,279	1,361	4,701
Other construction aggregate and roadstone	5,702	12,758	5,736	14,047	7,234	19,093
Riprap and jetty stone	1,637	3,800	1,464	3,934	850	3,070
Railroad ballast	1,504	3,765	1,372	3,465	1,153	3,425
Filter stone	267	800	323	1,100	344	1,271
Manufactured fine aggregate (stone sand)	740	2,463	1,068	3,846	1,092	4,283
Terrazzo and exposed aggregate	29	356	26	456	254	1,627
Cement manufacture	664	2,238	743	2,477	744	2,535
Ferrosilicon	84	575	115	586	191	1,348
Flux stone	1,439	6,025	874	3,885	1,110	6,081
Refractory stone	809	5,599	584	4,450	469	6,103
Abrasives	97	686	40	283	72	587
Asphalt filler	--	--	--	--	7	40
Other fillers or extenders	162	2,128	97	819	110	916
Glass manufacture	915	6,102	31	148	W	W
Roofing granules	769	1,788	810	1,874	W	W
Dam construction	--	--	--	--	23	45
Fill	312	624	474	732	443	673
Other uses[1]	233	1,604	520	1,909	1,316	4,251
Total[2]	30,187	91,210	28,262	86,295	31,188	106,621

W Withheld to avoid disclosing company proprietary data; included with "Other uses."

[1] Includes porcelain (1977 and 1978), building products (1977 and 1978), poultry grit, mine dusting (1979), drain fields, waste material (1977).

[2] Data may not add to totals shown because of independent rounding.

Table 27.—Dimension marble sold or used by producers in the United States, by use

Use	1977			1978			1979		
	Short tons	Cubic feet (thousands)	Value (thousands)	Short tons	Cubic feet (thousands)	Value (thousands)	Short tons	Cubic feet (thousands)	Value (thousands)
Rough stone:									
Rough blocks	16,196	185	$586	15,304	175	$537	5,846	61	$364
Irregular-shaped stone	41,391	484	1,609	36,176	410	1,356	33,450	371	1,661
Rubble	5,088	57	167	3,600	41	112	3,597	42	118
Flagging	1,544	18	70	9,014	100	563	975	11	42
Dressed stone:									
Cut stone	4,860	57	1,471	6,386	72	1,757	3,597	41	2,492
Sawed stone	8,610	95	2,049	9,937	110	2,292	16,781	190	6,552
Monumental	13,552	156	5,217	15,083	175	6,135	W	W	W
Other uses[1]	5,414	61	978	19,618	219	1,037	15,474	175	2,904
Total[2]	96,654	1,113	12,148	115,118	1,302	13,788	79,720	891	14,135

W Withheld to avoid disclosing company proprietary data; included with "Other uses."

[1] Includes house stone veneer, rough monumental stone, dressed construction stone, and dressed flagging (1977).

[2] Data may not add to totals shown because of independent rounding.

Table 28.—Crushed marble sold or used by producers in the United States, by use

(Thousand short tons and thousand dollars)

Use	1977		1978		1979	
	Quantity	Value	Quantity	Value	Quantity	Value
Poultry grit and mineral food	1	25	W	W	16	163
Bituminous aggregate	--	--	14	50	W	W
Other construction aggregate and roadstone	189	382	W	W	--	--
Manufactured fine aggregate (stone sand)	8	161	8	161	W	W
Terrazzo and exposed aggregate	171	3,843	164	3,716	200	4,919
Whiting or whiting substitute	W	W	W	W	276	2,567
Other fillers or extenders	860	14,046	W	W	W	W
Other uses[1]	311	5,490	1,233	21,219	970	17,435
Total[2]	1,540	23,947	1,417	25,146	1,461	25,085

W Withheld to avoid disclosing company proprietary data; included with "Other uses."

[1] Includes roofing granules, concrete aggregate, roadbase aggregate, and macadam aggregate (1977).

[2] Data may not add to totals shown because of independent rounding.

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Table 29.—Dimension slate sold or used by producers in the United States, by use

Use	1977		1978		1979	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
House stone veneer	190	$3	190	$4	W	W
Flagging	23,310	1,120	17,474	1,026	35,362	$1,632
Roofing slate-standard	9,934	2,338	8,326	2,302	9,520	3,114
Structural and sanitary	11,419	3,118	8,051	2,811	8,675	3,583
Blackboards, bulletin boards, school slates	134	107	215	51	146	58
Billard table tops	2,090	451	844	238	W	W
Flooring slate	6,349	955	11,574	1,494	22,956	4,082
Other uses[1]	3,839	152	6,372	302	10,623	352
Total[2]	57,265	8,244	53,046	8,228	87,282	12,821

W Withheld to avoid disclosing company proprietary data; included with "Other uses."

[1] Includes electrical fixtures (1977-78), and roofing slate-architectural (1979).

[2] Data may not add to totals shown because of independent rounding.

Table 30.—Crushed shell sold or used by producers in the United States, by use

(Thousand short tons and thousand dollars)

Use	1977		1978		1979	
	Quantity	Value	Quantity	Value	Quantity	Value
Poultry grit and mineral food	380	770	486	1,266	415	1,100
Bituminous aggregate	139	444	W	W	W	W
Dense-graded roadbase stone	4,860	15,671	3,083	9,754	3,344	11,828
Other construction aggregate and roadstone	4,643	10,474	4,891	13,325	5,392	17,468
Cement manufacture	2,108	3,787	1,915	4,233	1,272	3,298
Other uses[1]	1,368	2,341	2,062	4,769	1,754	4,878
Total[2]	13,492	33,487	12,436	33,346	12,177	38,572

W Withheld to avoid disclosing company proprietary data; included with "Other uses."

[1] Includes lime, fill, and riprap.

[2] Data may not add to totals shown because of independent rounding.

Table 31.—Other dimension stone sold or used by producers in the United States, by use

Use	1977			1978			1979		
	Short tons	Cubic feet (thousands)	Value (thousands)	Short tons	Cubic feet (thousands)	Value (thousands)	Short tons	cubic feet (thousands)	Value (thousands)
Rough stone:									
Rough blocks	1,500	19	$38	1,500	19	$38	1,500	19	$41
Irregular-shaped stone	14,445	176	426	9,347	113	354	13,551	163	429
Rubble	5,486	67	109	4,671	57	100	5,690	69	149
Flagging	88	1	4	181	2	9	101	1	6
Dressed stone: House stone veneer	150	2	4	175	2	4	--	--	--
Other uses[1]	3,146	37	322	3,032	36	309	2,975	34	303
Total[2]	24,815	301	903	18,906	228	814	23,817	287	928

[1] Includes dressed construction stone, cut stone, structural shapes, dressed flagging, and sawed stone (1977).

[2] Data may not add to totals shown because of independent rounding.

Table 32.—Other crushed stone sold or used by producers in the United States, by use

(Thousand short tons and thousand dollars)

Use	1977 Quantity	1977 Value	1978 Quantity	1978 Value	1979 Quantity	1979 Value
Concrete aggregate	774	1,567	375	855	318	911
Bituminous aggregate	983	3,023	545	1,711	519	1,657
Macadam aggregate	256	559	443	1,399	372	1,221
Dense-graded roadbase stone	5,680	13,749	4,907	11,987	5,478	14,915
Surface treatment aggregate	284	686	394	869	751	2,093
Other construction aggregate and roadstone	3,598	7,822	4,062	9,023	3,669	8,836
Riprap and jetty stone	676	1,199	823	1,754	1,006	2,233
Railroad ballast	148	335	46	106	45	111
Filter stone	21	50	13	38	12	35
Terrazzo and exposed aggregate	12	58	11	72	64	288
Abrasives	1	1	--	--	--	--
Other fillers	W	W	W	W	2	10
Fill	374	610	243	378	9	15
Roofing granules	W	W	W	W	32	148
Other uses[1]	38	150	29	124	202	656
Total[2]	12,843	29,806	11,891	28,317	12,479	33,128

W Withheld to avoid disclosing company proprietary data; included with "Other uses."

[1] Includes cement manufacture (1977).

[2] Data may not add to totals shown because of independent rounding.

Table 33.—Unit values of stone sold or used by producers in the United States

Stone	1977			1978			1979		
	Dimension stone			Dimension stone			Dimension stone		
	Per ton	Per cubic foot	Crushed stone, per ton	Per ton	Per cubic foot	Crushed stone, per ton	Per ton	Per cubic foot	Crushed stone, per ton
Limestone	$42.54	$3.24	$2.38	$53.98	$4.05	$2.56	$55.03	$4.20	$2.88
Granite	99.83	r10.10	2.55	104.38	9.62	2.78	110.41	10.07	3.15
Traprock	25.58	2.17	2.68	17.69	1.50	2.85	25.09	2.10	3.22
Sandstone	37.02	2.86	3.02	38.55	3.14	3.06	39.85	3.46	3.42
Marble	125.68	10.91	15.55	119.77	10.59	17.74	177.30	15.85	17.17
Slate	143.96	13.09	8.58	155.10	14.10	9.24	146.89	13.36	8.94
Shell	--	--	2.48	--	--	2.68	--	--	3.17
Marl	--	--	1.49	--	--	1.69	--	--	1.71
Miscellaneous	36.39	3.00	2.32	43.06	3.57	2.38	38.98	3.24	2.65
Average	73.38	r6.31	r2.47	81.11	6.86	2.64	87.29	7.43	2.98

r Revised.

Table 34.—Exports of dimension stone, by destination and type[1]

(Thousand short tons)

Type	Canada			Japan			Other			Total		
	1977	1978	1979	1977	1978	1979	1977	1978	1979	1977	1978	1979
Granite:												
Rough blocks	11	46	28	15	36	35	2	7	14	28	89	77
Other	--	4	3	--	15	1	--	9	5	--	28	9
Total	11	50	31	15	51	36	2	[2]16	[3]19	28	117	86
Limestone:												
Rough blocks	--	53	12	--	--	--	--	1	47	--	54	59
Other	7	31	7	--	--	--	[4]5	1	1	12	32	8
Total	7	84	19	--	--	--	5	2	[5]48	12	86	67
Marble	8	55	7	([6])	([6])	--	([6])	[7]6	[8]20	8	61	27
Slate	2	3	6	([6])	([6])	1	[9]5	[10]8	[11]4	7	11	11
Other:												
Rough blocks	31	13	6	1	1	15	15	([6])	5	47	14	26
Other including alabaster	--	2	2	--	([6])	1	--	3	5	--	5	8
Total	31	15	8	1	1	16	[12]15	[13]3	[14]10	47	19	34
Grand total	59	207	71	16	52	53	27	35	101	102	294	225

[1] Partly estimated from reported values.
[2] Primarily Austria, Italy, and Mexico, in order of volume.
[3] Primarily Costa Rica, Italy, Austria, Mexico, the United Kingdom, and Saudia Arabia, in order of volume.
[4] Primarily Venezuela and Chile, in order of volume.
[5] Included 40,000 tons to Venezuela and 6,000 tons to Chile.
[6] Less than 500 tons.
[7] Primarily the Bahamas, Mexico, and Saudia Arabia, in order of volume.
[8] Primarily Taiwan, Saudia Arabia, Mexico, the Bahamas, the Netherlands Antilles, and Ecuador, in order of volume.
[9] Primarily Sweden.
[10] Primarily Saudia Arabia, Trinidad, Venezuela, and Lebanon, in order of volume.
[11] Primarily Saudia Arabia.
[12] Primarily Iran, Mexico, Netherlands Antilles, Brazil, Venezuela, the Bahamas, the United Kingdom, and the Republic of Korea, in order of volume.
[13] Primarily the Federal Republic of Germany and Iraq.
[14] Primarily Belgium, the Federal Republic of Germany, and the United Arab Emirates, in order of volume.

Table 35.—Exports of crushed stone, by destination and type

(Thousand short tons)

Country	Limestone			Other[1]			Total		
	1977	1978	1979	1977	1978	1979	1977	1978	1979
North America:									
Bahamas	--	--	(2)	1	28	88	1	28	88
Canada	3,221	3,583	3,629	661	239	132	3,882	3,882	3,761
Mexico	10	2	(2)	24	53	8	34	55	8
Other[3]	1	9	7	(2)	1	5	1	10	12
Total	3,232	3,594	3,636	686	321	233	3,918	3,915	3,869
South America:									
Venezuela	1	3	301	1	2	2	2	5	303
Other	(2)	[4]3	1	(2)	(2)	2	(2)	3	3
Total	1	6	302	1	2	4	2	8	306
Europe:									
France	--	--	--	(2)	3	20	(2)	3	20
United Kingdom	(2)	(2)	(2)	(2)	8	11	1	8	11
Germany, Federal Republic of	--	--	--	(2)	45	3	(2)	45	3
Other	(2)	(2)	1	(2)	[5]14	[6]16	1	15	17
Total	1	(2)	1	1	70	50	2	71	51
Asia[7]	(2)	(2)	(2)	1	6	8	1	6	8
Oceania	(2)	(2)	(2)	4	(2)	1	4	(2)	1
Grand total	3,235	3,600	3,939	694	409	296	3,929	4,009	4,235

[1] Includes quartzite and slate.
[2] Less than 500 tons.
[3] Primarily Costa Rica and the Dominican Republic, in order of tonnage.
[4] Primarily Ecuador and Guyana, in order of tonnage.
[5] Primarily Belgium and the Netherlands, in order of tonnage.
[6] Primarily Sweden, the Netherlands, Belgium, and Denmark, in order of tonnage.
[7] Primarily Japan, the Republic of Korea, the Phillipines, and India.

Table 36.—U.S. imports of dimension stone, by type

Type	1977 Quantity	1977 Customs value (thousands)	1978 Quantity	1978 Customs value (thousands)	1979 Quantity	1979 Customs value (thousands)
Granite:						
Rough blocks ___thousand cubic feet__	215	$2,122	215	$2,549	201	$2,787
Dressed including monumental _do____	231	4,610	256	5,672	396	9,713
Other, n.a.p.f.	(1)	163	(1)	222	(1)	335
Total	XX	6,895	XX	8,443	XX	12,835
Marble, breccia, and onyx:						
In block, rough, or squared _ cubic feet__	20,443	161	34,138	179	14,798	241
Sawed or dressed, over 2 inches thick do____	2,195	43	4,151	32	1,003	19
Slabs and tiles__thousand square feet__	7,656	10,324	8,604	14,095	8,382	17,518
All other manufactures	(1)	8,963	(1)	11,927	(1)	14,019
Total	XX	19,491	XX	26,232	XX	31,797
Travertine stone:						
Rough, unmanufactured___ cubic feet__	5,941	25	5,183	34	15,838	99
Dressed, suitable for monumental and other uses __________short tons__	15,505	3,016	23,828	5,119	42,182	8,544
Other, n.a.p.f.	(1)	307	(1)	478	(1)	622
Total	XX	3,348	XX	5,631	XX	9,265
Limestone:						
Rough blocks __________cubic feet__	15,242	21	18,785	28	105,226	71
Dressed manufactured____short tons__	3,072	49	621	42	289	109
Other, n.a.p.f.	(1)	97	(1)	65	(1)	51
Total	XX	167	XX	135	XX	231
Slate:						
Roofing _____________ square feet__	--	--	--	--	86,200	22
Other, n.a.p.f.	(1)	4,239	(1)	5,658	(1)	6,570
Total	XX	4,239	XX	5,658	XX	6,592
Stone and articles of stone, n.a.p.f.:						
Statuary and sculptures___short tons__	(1)	313	(1)	313	(1)	518
Stone, unmanufactured _______do____	6,186	126	6,847	144	12,230	204
Building stone, rough ____cubic feet__	22,264	32	22,675	28	19,399	30
Building stone, dressed ___short tons__	258	51	478	81	530	68
Other including alabaster	(1)	3,247	(1)	5,057	(1)	4,299
Total	XX	3,769	XX	5,623	XX	5,119
Grand total	XX	37,909	XX	51,717	XX	65,839

XX Not applicable.
[1] Quantity not reported.

Table 37.—U.S. imports of crushed stone and fines, by type

Type	1977 Quantity	1977 Customs value (thousands)	1978 Quantity	1978 Customs value (thousands)	1979 Quantity	1979 Customs value (thousands)
Crushed stone and chips:						
Limestone ____ thousand short tons__	2,041	$4,094	2,138	$4,800	2,302	$5,434
Marble, breccia, onyx ____short tons__	1,761	61	2,873	105	15,282	210
Quartzite ____ thousand short tons__	67	527	91	908	109	822
Slate ______________short tons__	(1)	2	233	11	281	4
Other _______ thousand short tons__	1,133	2,344	1,464	3,088	1,482	3,484
Total _______do____	3,243	7,028	3,696	8,912	3,858	9,964
Calcium carbonate fines:						
Chalk, natural crude _________do____	516	925	546	615	461	609
Chalk, whiting____________do____	33	2,159	33	2,615	34	3,282
Precipitated _____________do____	8	1,264	11	2,107	9	2,146
Total _______do____	557	4,348	590	5,337	504	6,027
Grand total _______do____	3,800	11,376	4,286	14,249	4,362	15,961

[1] Quantity not reported.

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Sulfur and Pyrites

By John E. Shelton[1]

Production, shipments, apparent consumption, exports, imports, and price of sulfur all increased in 1979. Stocks of elemental sulfur decreased 21%. The average net shipment value f.o.b. mine/plant for Frasch and recovered elemental sulfur increased from $44.38 per metric ton in 1977 to $45.17 per ton in 1978 and to $55.75 per ton in 1979. The 1979 yearend quoted price for Frasch sulfur was $87.60 per metric ton, Gulf Ports and $94.24 per metric ton, exterminal Tampa. All data are in metric units.

Production of sulfur in all forms in 1979 reached a new high as output of Frasch sulfur reversed the 4-year downward trend. For the fourth year, however, domestic production was less than apparent domestic consumption. Production of elemental sulfur was concentrated in Texas and Louisiana. Together, these two States accounted for 64% of the total output in 1979.

To meet increased domestic demand and supply shortages caused by interruption of transport of sulfur from other world export-

Table 1.—Salient sulfur statistics

(Thousand metric tons, sulfur content, and thousand dollars unless otherwise noted)

	1975	1976	1977	1978	1979
United States:					
Production:					
Frasch	7,327	6,365	5,915	5,648	6,357
Recovered elemental	3,017	3,188	3,624	4,062	4,070
Other forms	1,096	1,326	1,188	1,465	1,674
Total	11,440	10,879	10,727	11,175	12,101
Shipments:					
Frasch	6,175	5,954	6,030	5,736	7,507
Recovered elemental	2,949	3,196	3,627	4,088	4,108
Other forms	1,096	1,326	1,188	1,465	1,674
Total	10,220	10,476	10,845	11,289	13,289
Imports, elemental and pyrites	1,927	1,755	2,009	2,177	2,494
Exports, crude and refined [1]	1,316	1,217	1,088	827	1,963
Consumption, apparent all forms[2]	10,773	10,941	11,657	12,000	13,739
Stocks, Dec. 31: Producer, Frasch and recovered elemental	5,208	5,652	5,557	5,345	4,229
Value:					
Shipments, f.o.b. mine or plant:					
Frasch	$304,843	$299,999	$294,733	$279,918	$449,433
Recovered elemental	104,886	118,322	133,849	163,799	198,137
Other forms	50,053	59,050	57,304	68,295	89,643
Total	459,782	477,371	485,886	512,012	737,213
Imports, elemental[3]	$70,848	$59,494	$65,154	$75,671	$94,147
Exports, crude and refined [3] [4]	$71,801	$63,584	$52,111	$34,667	$142,966
Price, elemental, dollars per metric ton, f.o.b. mine or plant	$44.91	$45.72	$44.38	$45.17	$55.75
World production: All forms (including pyrites)	50,678	50,868	52,093	53,399	54,834

[1] Excludes exports from the Virgin Islands to foreign countries.
[2] Measured by shipments, plus imports, minus exports.
[3] Declared customs valuation.
[4] Excludes value of exports from the Virgin Islands to foreign countries.

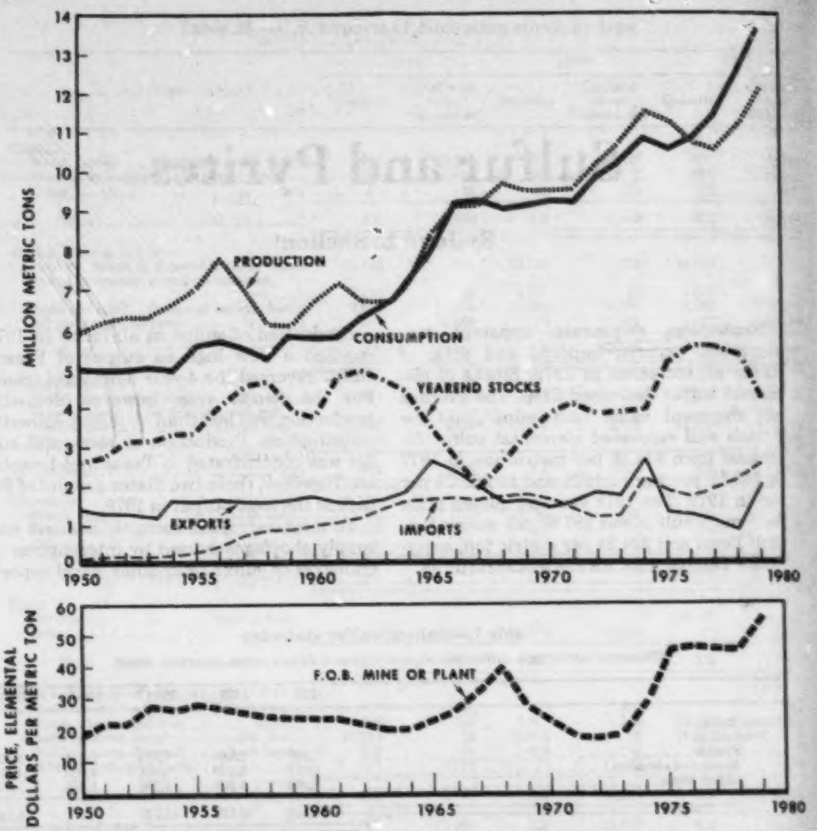

Figure 1.—Trends in the sulfur industry in the United States.

ers, shipments of sulfur in all forms by U.S. producers to domestic and export markets were 13.3 million tons, 18% over those in 1978. The total value of shipments f.o.b. mine/plant was $512.0 million in 1978 and $737 million in 1979. The apparent domestic consumption of sulfur in all forms reached a new high of 13.7 million tons in 1979. The United States was a net importer again in 1979, despite the large increase in exports of sulfur.

Legislation and Government Programs.—The United States Customs Service, Department of the Treasury, issued a notice that it appears that elemental sulfur from Canada and Mexico was no longer being sold at less than fair value within the meaning of the Antidumping Act of 1921.[2] A rule establishing standards of performance will limit emissions of sulfur dioxide and reduced sulfur compounds from new, modified, and reconstructed petroleum refinery Claus sulfur recovery plants.[3] The University of Arizona, under contract with the Bureau of Mines, is evaluating sources of sulfur and the impact of byproduct sulfur recovered in meeting environmental requirements to 2000.

DOMESTIC PRODUCTION

Frasch Sulfur.—In 1979, there were eight Frasch mines, all in Louisiana and Texas. Mines in Louisiana were Freeport Minerals Co. at Garden Island Bay and Grand Isle. Producers' mines in Texas were Farmland Industries, Inc., at Fort Stockton; Duval Corp. at Culberson; Jefferson Lake Sulfur Co. at Long Point Dome; and Texasgulf, Inc., at Boling Dome, Moss Bluff Dome, and at Comanche Creek. Production was stopped at Texasgulf Inc.'s Bully Camp mine in July 1978 and at Freeport Minerals Co.'s Grand Ecaille mine in December 1978. The six mines operated by Duval Corp., Freeport Minerals Co., and Texasgulf, Inc., accounted for most of the Frasch sulfur production. A relatively small portion of the output was from the other two producers operating one mine each.

Of producers' shipments of Frasch sulfur, 26% were for export. The value of Frasch sulfur shipments in 1979 reached a new high of $449 million. Reported stocks after inventory adjustments were drawn down by more than 1 million tons to 4,058,000 metric tons.

Recovered Sulfur.—Production of recovered elemental sulfur, a nondiscretionary byproduct from natural gas and petroleum refinery operations, electric utilities, and a coking plant, reached an alltime high in 1979 of 4.1 million tons. This type of sulfur was produced by 56 companies at 152 plants in 28 States, 2 plants in Puerto Rico, and 1 in the Virgin Islands. Most of the plants were of relatively small size, with only six reporting an annual production exceeding 100,000 tons. The 10 largest plants accounted for 44% of the output. By source, 57% was produced by 39 companies at 82 refineries or satellite plants treating refinery gases, 1 coking operation, and 2 utility plants, and 43% was produced by 27 companies at 67 natural gas treatment plants. The five largest recovered elemental sulfur producers were Atlantic Richfield Co.; Chevron U.S.A., Inc.; Exxon Co., U.S.A.; Shell Oil Co.; and Standard Oil Co. (Indiana). Together, their 44 plants accounted for 61% of recovered elemental sulfur production in 1979.

Table 2.—Production of sulfur and sulfur-containing raw materials by producers in the United States

(Thousand metric tons)

	1976		1977		1978		1979	
	Gross weight	Sulfur content	Gross weight	Sulfur content	Gross weight	Sulfur content	Gross weight	Sulfur content
Frasch sulfur	6,365	6,365	5,915	5,915	5,648	5,648	6,357	6,357
Recovered elemental sulfur	3,188	3,188	3,624	3,624	4,062	4,062	4,070	4,070
Byproduct sulfuric acid (basis 100%) produced at copper, zinc, and lead plants	2,927	957	2,936	960	3,373	1,103	3,570	1,167
Pyrites	762	291	442	169	778	301	1,049	400
Other forms[1]	118	78	85	59	93	61	182	107
Total	--	10,879	--	10,727	--	11,175	--	12,101

[1] Hydrogen sulfide and liquid sulfur dioxide.

Table 3.—Sulfur produced and shipped from Frasch mines in the United States

(Thousand metric tons and thousand dollars)

Year	Production			Shipments	
	Texas	Louisiana	Total	Quantity	Value[1]
1975	4,208	3,119	7,327	6,175	304,843
1976	3,838	2,527	6,365	5,954	299,999
1977	3,454	2,461	5,915	6,030	294,733
1978	3,720	1,928	5,648	5,796	279,918
1979	3,897	2,460	6,357	7,507	449,433

[1] F.o.b. mine.

Table 4.—Recovered sulfur produced and shipped in the United States

(Thousand metric tons and thousand dollars)

Year	Production: Natural gas plants	Production: Petroleum refineries[1]	Production: Total	Shipments: Quantity	Shipments: Value[2]
1975	1,364	1,653	3,017	2,949	104,886
1976	1,298	1,890	3,188	3,196	118,332
1977	1,426	2,198	3,624	3,627	133,349
1978	1,753	[3]2,309	4,062	4,088	163,790
1979	1,760	[3]2,310	4,070	4,108	198,137

[1] Includes a small quantity from a coking operation.
[2] F.o.b. plant.
[3] Includes a small quantity from utility plants.

Table 5.—Recovered sulfur produced and shipped in the United States, by State

(Thousand metric tons and thousand dollars)

State	1978: Production (quantity)	1978: Shipments: Quantity	1978: Shipments: Value	1979: Production (quantity)	1979: Shipments: Quantity	1979: Shipments: Value
Alabama	465	404	18,420	373	375	20,318
California	443	440	10,227	475	493	12,261
Florida	341	341	W	335	335	W
Illinois	202	200	7,867	196	196	8,289
Indiana	71	71	2,543	62	61	2,542
Kansas	17	17	553	22	23	1,008
Louisiana	185	183	8,013	186	186	11,068
Michigan and Minnesota	79	79	2,369	84	85	2,865
Mississippi	493	517	24,917	539	563	35,618
New Jersey	120	119	5,446	108	109	5,668
New Mexico	64	64	2,220	67	66	3,051
Ohio	23	23	920	23	23	986
Oklahoma	9	9	355	11	11	461
Pennsylvania	74	74	3,133	70	71	3,222
Texas	1,107	1,099	46,436	1,081	1,094	54,551
Wisconsin	2	1	30	1	1	34
Wyoming	48	53	W	47	48	W
Other States[1]	379	394	30,340	388	379	35,971
Total[2]	4,062	4,088	163,790	4,070	4,108	198,137

W Withheld to avoid disclosing company proprietary data; included with "Other States."
[1] Combined to avoid disclosing company proprietary data; includes Arkansas, Colorado 1978, Delaware, Kentucky, Missouri, Montana, New York, North Dakota, Utah, Virginia, Washington, Virgin Islands, and Puerto Rico.
[2] Data may not add to totals shown because of independent rounding.

The leading States in production of recovered elemental sulfur were Texas, Mississippi, California, Alabama, and Florida. Together these States contributed 69% of the total 1979 output. The total value of shipments of recovered elemental sulfur in 1979 was an alltime high of $198 million.

Byproduct Sulfuric Acid.—Production of byproduct sulfuric acid at copper, lead, and zinc smelters and roasters reached new highs in 1978 and again in 1979. In 1979, byproduct sulfuric acid was produced by 13 companies at 26 plants in 13 States. Thirteen acid plants operated in conjuction with copper smelters and 13 plants were accessories to lead and zinc roasting and smelting operations. The five largest acid plants accounted for 49% of the output, and production in five States was 77% of the total. The five largest producers of byproduct sulfuric acid were ASARCO Inc., Magma Copper Co., Kennecott Copper Corp., Phelps Dodge Corp., and St. Joe Minerals Corp., whose 16 plants produced 72% of the byproduct sulfuric acid in 1979.

Table 6.—Byproduct sulfuric acid[1] (sulfur content) produced in the United States

(Thousand metric tons and thousand dollars)

Year	Copper plants[2]	Lead and zinc plants[3]	Total	Value
1975	529	250	779	42,965
1976	677	230	907	46,151
1977	699	261	960	46,238
1978	812	291	1,103	49,848
1979	821	346	1,167	51,815

[1] Includes acid from foreign materials.
[2] Excludes acid made from pyrites concentrates.
[3] Excludes acid made from native sulfur.

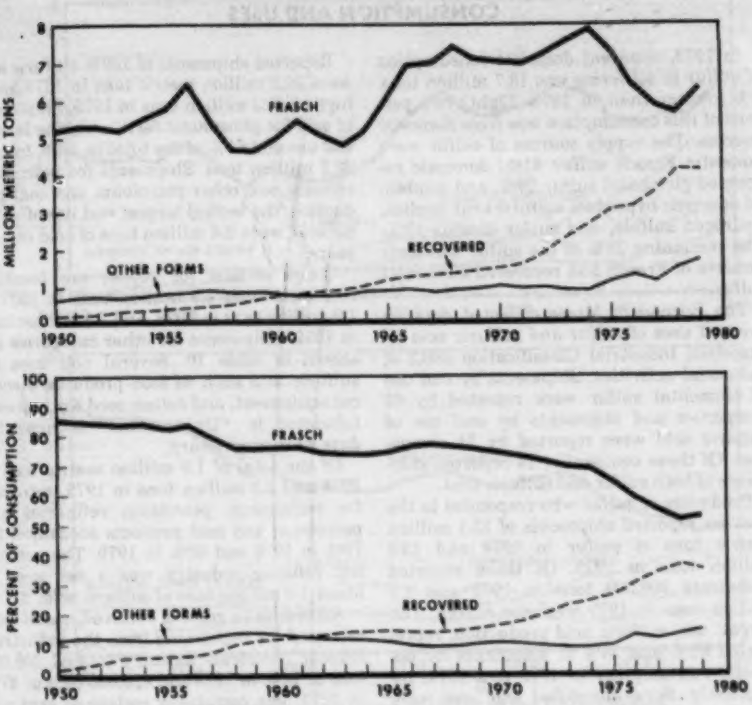

Figure 2.—Trends in the production of sulfur in the United States.

Pyrites, Hydrogen Sulfide, and Sulfur Dioxide.—In 1978 and 1979 pyrites was produced by three companies at three mines in three States and hydrogen sulfide by three companies at four plants in three States. In 1978 sulfur dioxide was produced by two companies at two plants in two States. In 1979 sulfur dioxide was produced by three companies at five plants in five States. In 1979 the three largest producers of these products were Cities Service Co., (pyrites and sulfur dioxide), Shell Oil Co. (hydrogen sulfide), and Stauffer Chemical Co. (sulfur dioxide). These companies combined, at one mine and six plants, accounted for 93% of the contained sulfur produced in the form of these products.

Table 7.—Pyrites, hydrogen sulfide, and sulfur dioxide sold or used in the United States

(Thousand metric tons sulfur content and thousand dollars)

Year	Pyrites	Hydrogen sulfide	Sulfur dioxide	Total	Value
1975	241	76	(1)	317	7,097
1976	291	78	(1)	369	12,980
1977	169	59	(1)	228	11,068
1978	301	61	(1)	362	18,447
1979	400	35	72	507	37,828

[1] Included with "Hydrogen sulfide," 1975-78.

CONSUMPTION AND USES

In 1979, apparent domestic consumption of sulfur in all forms was 13.7 million tons, 9% greater than in 1978. Eighty-two percent of this consumption was from domestic sources. The supply sources of sulfur were domestic Frasch sulfur 41%, domestic recovered elemental sulfur 29%, and combined domestic byproduct sulfuric acid, pyrites, hydrogen sulfide, and sulfur dioxide 12%. The remaining 18% of the sulfur was from imports of Frasch and recovered elemental sulfur.

The Bureau of Mines collected data on the end uses of sulfur and sulfuric acid by Standard Industrial Classification (SIC) of industrial activities. Shipments by end use of elemental sulfur were reported by 63 companies and shipments by end use of sulfuric acid were reported by 71 companies. Of these companies, 14 reported shipments of both sulfur and sulfuric acid.

Producers of sulfur who responded to the canvass reported shipments of 12.1 million metric tons of sulfur in 1978 and 13.3 million tons in 1979. Of these reported shipments 900,000 tons in 1978 and 1.9 million tons in 1979 were for export. The largest use, sulfuric acid production, represented 83% and 84% of shipments for domestic consumption in 1978 and 1979, respectively. Some identified end uses were tabulated in the unidentified uses because data were proprietary. Data collected on other forms from some companies who did not identify shipments by end use were also tabulated as unidentified.

Reported shipments of 100% sulfuric acid were 36.2 million metric tons in 1978 and a high of 38.2 million tons in 1979. Shipments of acid for phosphatic fertilizers, the largest end use and 61% of the total in 1979, totaled 23.2 million tons. Shipments for petroleum refining and other petroleum and coal production, the second largest end use of sulfuric acid, were 2.4 million tons of acid in both years.

Usage of acid for copper ore leaching increased from 1.8 million tons in 1977 to 1.9 million tons in 1978, and 2.1 million tons in 1979. Shipments for other categories are shown in table 10. Several end uses for sulfuric acid such as food products, electrical equipment, and cotton seed linting were tabulated in "Unidentified" because the data were proprietary.

Of the total of 1.9 million metric tons in 1978 and 2.3 million tons in 1979, returned for reclaiming, petroleum refineries and petroleum and coal products accounted for 70% in 1978 and 62% in 1979. The petroleum refining industry was a net user of about 1.0 million tons of sulfuric acid.

According to reports received, spent acid returned for reclaiming from the industrial organic chemicals industry totaled 259,000 tons or 14% in 1978 and 616,000 tons or 27% in 1979. The remaining reclaimed acid was from production of phosphatic fertilizers, other chemical products, inorganic pigments, soaps and detergents, explosives, other agricultural chemicals, other inorganic chemicals, pesticides, and water treating.

Table 8.—Apparent consumption of sulfur in the United States[1]

(Thousand metric tons)

	1975	1976	1977	1978	1979
Frasch:					
Shipments	6,175	5,964	6,030	5,736	7,507
Imports	982	743	781	993	1,229
Exports	1,316	1,217	1,088	827	1,963
Total	5,841	5,490	5,723	5,902	6,773
Recovered:					
Shipments	2,949	3,196	3,627	4,088	4,108
Imports	945	1,012	1,228	1,185	1,265
Exports from the Virgin Islands	58	73	109	39	81
Total	3,836	4,135	4,746	5,234	5,292
Pyrites, shipments	241	291	169	301	400
Byproduct sulfuric acid	779	957	960	1,103	1,167
Other forms[2]	76	78	59	61	107
Total all forms	10,773	10,941	11,657	[3]12,600	13,739

[1] Crude sulfur or sulfur content.

[2] Includes consumption of hydrogen sulfide and liquid sulfur dioxide.

[3] Data may not add to totals shown because of independent rounding.

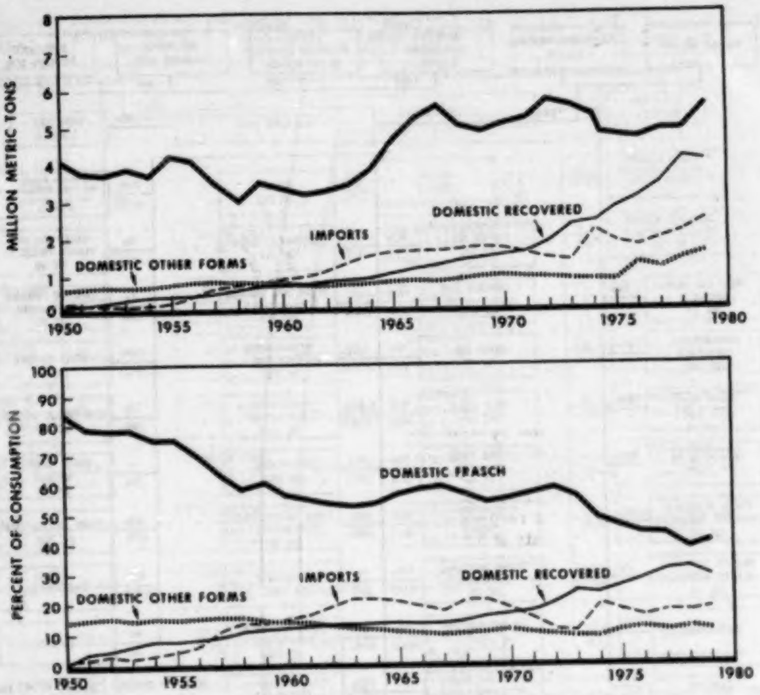

Figure 3.—Trends in the consumption of sulfur in the United States.

Table 11 shows the domestic uses of sulfur including the sulfur contained in sulfuric acid. The largest identified end use for sulfur (as sulfuric acid) was for phosphatic fertilizers, which accounted for 50% in 1978 and 53% in 1979 of the total use of sulfur.

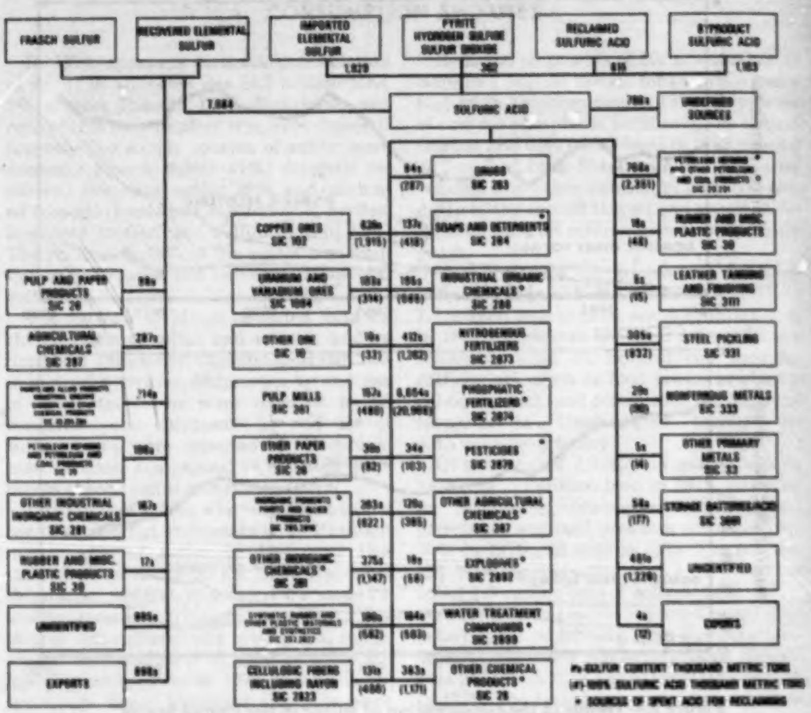
FRASCH SULFUR
RECOVERED ELEMENTAL SULFUR
IMPORTED ELEMENTAL SULFUR
PYRITE HYDROGEN SULFIDE SULFUR DIOXIDE
RECLAIMED SULFURIC ACID
BYPRODUCT SULFURIC ACID
1,929
362
1,183
7,064
SULFURIC ACID
UNDEFINED SOURCES
DRUGS SIC 283
COPPER ORES SIC 102
SOAPS AND DETERGENTS SIC 284
PULP AND PAPER PRODUCTS SIC 26
URANIUM AND VANADIUM ORES SIC 1094
INDUSTRIAL ORGANIC CHEMICALS SIC 286
AGRICULTURAL CHEMICALS SIC 287
OTHER ORE SIC 10
NITROGENOUS FERTILIZERS SIC 2873
PULP MILLS SIC 261
PHOSPHATIC FERTILIZERS SIC 2874
OTHER PAPER PRODUCTS SIC 26
PESTICIDES SIC 2879
OTHER INDUSTRIAL INORGANIC CHEMICALS SIC 281
OTHER AGRICULTURAL CHEMICALS SIC 287
RUBBER AND MISC. PLASTIC PRODUCTS SIC 30
OTHER INORGANIC CHEMICALS SIC 281
EXPLOSIVES SIC 2892
UNIDENTIFIED
WATER TREATMENT COMPOUNDS SIC 2899
EXPORTS
CELLULOSIC FIBERS INCLUDING RAYON SIC 2823
OTHER CHEMICAL PRODUCTS SIC 28
RUBBER AND MISC. PLASTIC PRODUCTS SIC 30
LEATHER TANNING AND FINISHING SIC 3111
STEEL PICKLING SIC 331
NONFERROUS METALS SIC 333
OTHER PRIMARY METALS SIC 33
STORAGE BATTERIES (ACID) SIC 3691
UNIDENTIFIED
EXPORTS
96s
287s
714s
108s
167s
17s
885s
898s
84s (287)
620s (1,915)
137s (418)
103s (314)
195s (600)
10s (33)
412s (1,262)
157s (480)
6,854s (20,966)
30s (92)
34s (103)
283s (822)
120s (385)
375s (1,147)
18s (56)
184s (563)
135s (406)
383s (1,171)
768s (2,351)
16s (48)
5s (15)
305s (932)
29s (90)
5s (14)
58s (177)
401s (1,228)
4s (12)
(s)-SULFUR CONTENT THOUSAND METRIC TONS
(#)-100% SULFURIC ACID THOUSAND METRIC TONS
* SOURCES OF SPENT ACID FOR RECLAIMING

Figure 4.—Sulfur-sulfuric acid supply/end-use relationship, 1978.

Table 9.—Elemental sulfur sold or used in the United States, by end use

(Thousand metric tons)

SIC	Use	1978	1979
20	Food and kindred products	W	W
26, 261	Pulp and paper products	96	124
282, 2822, 2823	Synthetic rubber, cellulosic fibers and other plastic products	W	W
287	Agricultural chemicals	287	272
28, 285, 286	Paints and allied products, industrial organic chemicals, and other chemical products	214	166
29,291	Petroleum refining and petroleum and coal products	108	108
281	Other industrial inorganic chemicals	167	192
30	Rubber and miscellaneous plastic products	17	18
	Sulfuric acid:		
	Domestic sulfur	7,064	7,793
	Imported sulfur	1,929	1,754
	Total sulfuric acid	8,993	9,547
	Unidentified	985	952
	Total domestic	10,867	11,374
	Exports	898	1,882
	Total	11,765	13,256

W Withheld to avoid disclosing company proprietary data; included with "Unidentified."

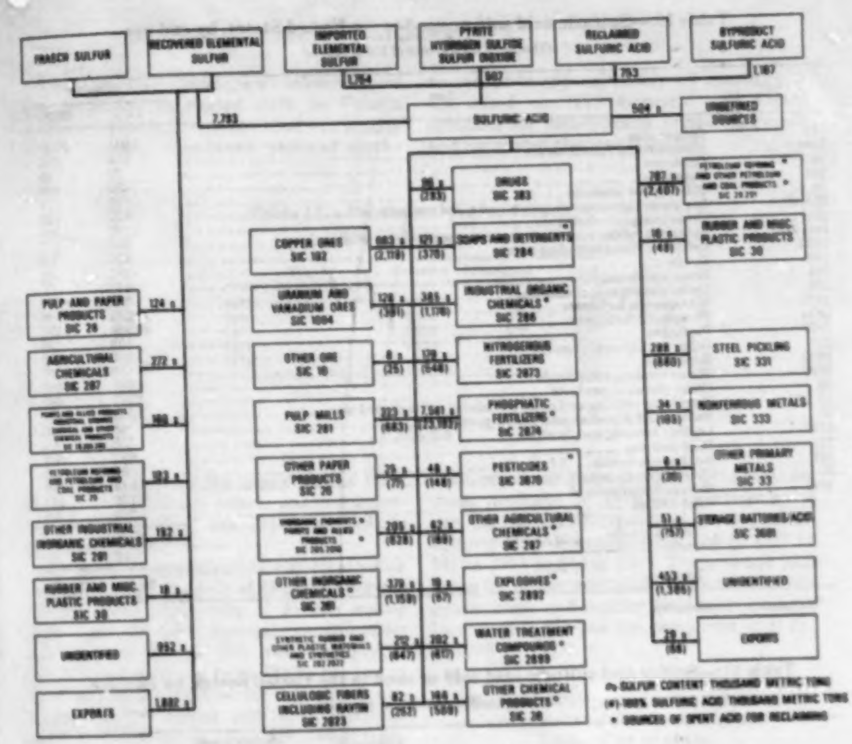
FRASCH SULFUR
RECOVERED ELEMENTAL SULFUR
IMPORTED ELEMENTAL SULFUR
PYRITE HYDROGEN SULFIDE SULFUR DIOXIDE
RECLAIMED SULFURIC ACID
BYPRODUCT SULFURIC ACID
1,764
907
753
1,187
7,783
SULFURIC ACID
504 s
UNIDENTIFIED SOURCES
DRUGS SIC 283
90 s (283)
COPPER ORES SIC 102
683 s (2,110)
121 s (370)
SOAPS AND DETERGENTS SIC 284
URANIUM AND VANADIUM ORES SIC 1094
128 s (391)
385 s (1,176)
INDUSTRIAL ORGANIC CHEMICALS SIC 286
OTHER ORE SIC 10
8 s (25)
120 s (648)
NITROGENOUS FERTILIZERS SIC 2873
PULP MILLS SIC 261
223 s (683)
7,581 s (23,197)
PHOSPHATIC FERTILIZERS SIC 2874
OTHER PAPER PRODUCTS SIC 26
25 s (77)
48 s (148)
PESTICIDES SIC 2879
205 s (628)
62 s (189)
OTHER AGRICULTURAL CHEMICALS SIC 287
OTHER INORGANIC CHEMICALS SIC 281
379 s (1,159)
19 s (57)
EXPLOSIVES SIC 2892
SYNTHETIC RUBBER AND OTHER PLASTIC MATERIALS AND SYNTHETICS SIC 282
212 s (647)
202 s (617)
WATER TREATMENT COMPOUNDS SIC 2899
CELLULOSIC FIBERS INCLUDING RAYON SIC 2823
82 s (252)
166 s (508)
OTHER CHEMICAL PRODUCTS SIC 28
PULP AND PAPER PRODUCTS SIC 26
124 s
AGRICULTURAL CHEMICALS SIC 287
272 s
160 s
PETROLEUM REFINING AND PETROLEUM AND COAL PRODUCTS SIC 29
103 s
OTHER INDUSTRIAL INORGANIC CHEMICALS SIC 281
192 s
RUBBER AND MISC. PLASTIC PRODUCTS SIC 30
18 s
UNIDENTIFIED
952 s
EXPORTS
1,882 s
PETROLEUM REFINING AND OTHER PETROLEUM AND COAL PRODUCTS SIC 29
787 s (2,407)
RUBBER AND MISC. PLASTIC PRODUCTS SIC 30
16 s (48)
STEEL PICKLING SIC 331
288 s (880)
NONFERROUS METALS SIC 333
34 s (105)
OTHER PRIMARY METALS SIC 33
6 s (20)
STORAGE BATTERIES/ACID SIC 3691
51 s (157)
UNIDENTIFIED
453 s (1,386)
EXPORTS
29 s (88)
s- SULFUR CONTENT THOUSAND METRIC TONS
(#)-100% SULFURIC ACID THOUSAND METRIC TONS
* SOURCES OF SPENT ACID FOR RECLAIMING

Figure 5.—Sulfur-sulfuric acid supply/end-use relationship, 1979.

Table 10.—Sulfuric acid sold or used in the United States, by end use

(Thousand metric tons of 100% H_2SO_4)

SIC	Use	Quantity	
		1978	1979
102	Copper ores	1,915	2,119
1094	Uranium and vanadium ore	314	391
10	Other ore	32	25
261	Pulpmills	480	683
26	Other paper products	92	77
285, 2816	Inorganic pigments and paints and allied products	622	628
281	Other inorganic chemicals	1,147	1,159
282, 2822	Synthetic rubber and other plastic materials and synthetics	582	647
2823	Cellulosic fibers including rayon	400	252
283	Drugs	287	293
284	Soaps and detergents	418	370
286	Industrial organic chemicals	595	1,178
2873	Nitrogenous fertilizers	1,262	546
2874	Phosphatic fertilizers	20,968	23,192
2879	Pesticides	103	148
287	Other agricultural chemicals	385	189
2892	Explosives	56	57
2899	Water treating compounds	503	617
28	Other chemical products	1,171	509
29, 291	Petroleum refining and other petroleum and coal products	2,351	2,407
30	Rubber and miscellaneous plastic products	48	49
3111	Leather tanning and finishing	15	([1])
331	Steel pickling	932	880
333	Nonferrous metals	90	105
33	Other primary metals	14	20
3691	Storage batteries/acid	177	157
	Unidentified	1,228	1,385
	Total domestic	36,187	38,083
	Exports	12	88
	Total	36,199	38,171

[1] Included in "Unidentified."

Table 11.—Sulfur and sulfuric acid sold or used in the United States, by end use

(Thousand metric tons sulfur content)

SIC	Use	Elemental sulfur[1]		Sulfuric acid (sulfur equivalent)		Total	
		1978	1979	1978	1979	1978	1979
102	Copper ores	--	--	626	693	626	693
1094	Uranium and vanadium ores	--	--	103	128	103	128
10	Other ores	--	--	10	8	10	8
20	Food and kindred products	W	W	--	--	W	W
261, 26	Pulpmills and paper products	96	124	187	248	283	372
2816, 285 28, 286	Inorganic pigments, paints and allied products, industrial organic chemicals, and other chemical products	214	166	203	205	417	371
281	Other inorganic chemicals	167	192	375	379	542	571
2822, 2823, 282	Synthetic rubber, cellulosic fibers, other plastic materials and synthetics	W	W	321	294	321	294
283	Drugs	--	--	94	96	94	96
284	Soaps and detergents	--	--	137	121	137	121
286	Industrial organic chemicals	--	--	195	385	195	285
2873	Nitrogenous fertilizers	--	--	412	179	412	179
2874	Phosphatic fertilizers	--	--	6,854	7,581	6,854	7,581
2879	Pesticides	--	--	34	48	34	48
287	Other agricultural chemicals	287	272	126	62	413	334
2892	Explosives	--	--	18	19	18	19
2899	Water treating compounds	--	--	164	202	164	202
28	Other chemical products	--	--	383	166	383	166
291, 29	Petroleum refining and other petroleum and coal products	108	103	768	787	876	890
30	Rubber and miscellaneous plastic products	17	18	16	16	33	34
3111	Leather tanning and finishing	--	--	5	W	5	W
331	Steel pickling	--	--	305	288	305	288
333	Nonferrous metals	--	--	29	34	29	34
33	Other primary metals	--	--	5	6	5	6
3691	Storage batteries	--	--	58	51	58	51
	Exported sulfuric acid	--	--	4	29	4	29
	Subtotal	889	875	11,432	12,025	12,321	12,900
	Unidentified	985	952	401	453	1,386	1,405
	Total	1,874	1,827	11,833	12,478	13,707	14,305

W Withheld to avoid disclosing company propietary data; included with "Unidentified."

[1] Does not include elemental sulfur used for production of sulfuric acid.

STOCKS

Yearend 1979 producers' inventory of Frasch sulfur decreased 21% as Frasch producers shipped from inventory to supply world markets. Combined yearend stocks amounted to approximately 4.4 months supply based on 1979 domestic and export demands for domestically produced Frasch and recovered elemental sulfur.

Table 12.—Producers' yearend stocks

(Thousand metric tons)

Year	Frasch	Recovered	Total
1975	4,935	273	5,208
1976	5,382	270	5,652
1977	5,288	269	5,557
1978	5,123	222	5,345
1979	4,058	181	4,239

PRICES

The quoted price for liquid sulfur Gulf Ports was $87.60 per metric ton and exterminal Tampa, Fla., was $94.24 per metric ton at yearend 1979.

On the basis of shipments and total value reported to the Bureau of Mines, the average value of shipments of Frasch sulfur f.o.b. mine for both domestic consumption and exports during 1979 rose sharply to $59.87 per metric ton from $48.80 per ton in 1978. Shipment values for recovered elemental sulfur varied widely in different regions; lowest in the West, somewhat higher in the midcontinent, and near the values for Frasch sulfur in the East and South. Overall, the reported unit shipment value for recovered elemental sulfur, f.o.b. plant, in 1979 was $48.23 per metric ton, compared with $40.07 per ton in 1978.

Marketing sulfur produced in other than the elemental form reflected competitive positions in the limited regional markets for these products. In 1979, the average price per ton of sulfur contained in byproduct sulfuric acid decreased from $48 in 1977 to $45 in 1978 to $44 in 1979. The average unit value for sulfur contained in pyrites, hydrogen sulfide, and sulfur dioxide, combined, increased to $75 per ton compared with $51 in 1978.

Table 13.—Reported sales values of shipments of elemental sulfur, f.o.b. mine or plant

(Dollars per metric ton)

Year	Frasch	Recovered	Total
1975	49.37	35.57	44.91
1976	50.38	37.02	45.72
1977	48.88	36.91	44.38
1978	48.80	40.07	45.17
1979	59.87	48.23	55.75

FOREIGN TRADE

The United States was a net importer of sulfur in 1979, for the fifth year. Exports in 1978 were down 28% from 1977 to about 0.9 million tons, but increased to 2 million tons in 1979. Imports in the form of elemental sulfur increased 8% to 2.2 million tons in 1978 and an additional 15% to 2.5 million tons in 1979.

Exports from the United States were almost entirely in the form of Frasch sulfur. The total value of exports in 1978 declined 33% below that of 1977 and increased 312% in 1979. The total value of average export value was $41.94 per ton in 1978 and $72.85 in 1979. In 1978 Belgium-Luxembourg and the Netherlands received 70% of the exports, mainly for transshipment to other European Community Countries. Exports to Belgium-Luxembourg and the Netherlands were 45% of the total in 1979 as larger quantities were shipped to other countries to fulfill demand. Not included in the above were exports from the Virgin Islands which were 39,308 tons valued at $1.5 million in 1978 and 80,772 tons valued at $6.2 million in 1979.

Imports of Frasch sulfur from Mexico were 993,000 tons in 1978 and 1,229,000 tons in 1979. Imports of recovered elemental sulfur, mostly from Canada totaled 1.2 million tons in 1978 and 1.3 million tons in 1979. The unit value of imports of sulfur from Canada increased $4.51 from $15.81 in 1978 to $19.32 in 1979, whereas the value of imports from Mexico decreased from $57.30 in 1978 to $56.67 in 1979.

Table 14.—U.S. exports of crude and refined sulfur, by country

(Thousand metric tons and thousand dollars)

Destination	1978		1979	
	Quantity	Value	Quantity	Value
Argentina	30	1,544	31	2,748
Australia	1	36	113	8,212
Belgium-Luxembourg	432	16,454	580	37,438
Brazil	49	2,453	190	9,320
Canada	40	1,522	7	471
Chile	(1)	29	13	1,181
Colombia	1	64	(1)	88
Czechoslovakia	16	890	--	--
Egypt	--	--	32	2,672
France	13	513	54	3,084
Greece	(1)	2	78	6,012
India	20	1,166	225	15,908
Italy	(1)	7	69	6,436
Lebanon	--	--	26	2,177
Mexico	6	171	5	316
Morocco	--	--	132	9,586
Netherlands	148	6,335	268	16,164
New Zealand	(1)	24	(1)	134
Peru	12	65	(1)	60
Romania	--	--	41	2,722
South Africa, Republic of	(1)	14	61	5,060
Spain	(1)	9	(1)	6
Trinidad	--	--	15	1,166
Tunisia	48	2,022	22	1,730
Uruguay	9	486	26	1,877
Other	13	892	20	4,826
Total[2]	827	34,667	1,368	142,906

[1] Less than 1/2 unit.

[2] Excludes exports from the Virgin Islands to foreign countries 1978: 39,308 metric tons ($1,470,936); 1979: 80,772 metric tons ($6,162,667); see table 15.

Table 15.—Sulfur exported from the Virgin Islands to foreign countries

(Thousand metric tons and thousand dollars)

Country	1978		1979	
	Quantity	Value	Quantity	Value
Brazil	8	321	--	--
Italy	--	--	14	720
Jamaica	2	81	--	--
Morocco	13	490	14	1,006
South Africa, Republic of	16	579	30	2,138
Tunisia	--	--	11	1,072
Turkey	--	--	12	1,197
Total	39	1,471	81	[1]6,163

[1] Data may not add to totals shown because of independent rounding.

Table 16.—U.S. imports of elemental sulfur, by country

(Thousand metric tons and thousand dollars)

Country	1978		1979	
	Quantity	Value	Quantity	Value
Canada	1,185	18,782	1,265	24,440
Germany, Federal Republic of	(1)	29	(1)	42
Mexico	992	56,856	1,229	69,648
Other[2]	(1)	13	(1)	17
Total	[3]2,177	75,671	2,494	94,147

[1] Less than 1/2 unit.

[2] 1978— France; 1979— France and the People's Democratic Republic of Yemen (Aden).

[3] Data may not add to totals shown because of independent rounding.

WORLD REVIEW

Despite interruptions in production and shipments of sulfur caused by harsh winter weather and accidents affecting shipping, world demand for sulfur was essentially met by augmenting shipments of newly produced sulfur with the drawdown of producer and consumer stocks.

Canada.—Production of sulfur in all forms totaled 7.2 million tons in 1978 and 6.9 million tons in 1979. Recovered elemental sulfur representing about 90% of the total output in 1979 was produced at 49 sour natural gas plants; 45 in Alberta, 3 in British Columbia, and 1 in Saskatchewan. Production of contained sulfur from smelter gases was 605,000 tons in 1979.[4]

Production of sulfur in Alberta was about 6.4 million tons in 1978 and 6.2 million tons in 1979. Of the total in 1979, 213,000 tons was from tar sands, 13,000 tons was from refinery output, and the remainder was from natural gas operations. Shipments increased from 5.0 million tons in 1977 to 5.6 million tons in 1978 and a record high of 6.1 million tons in 1979. Of shipments in 1979, 4.1 million tons were exports to off shore markets other than the United States. Producers' plant stocks in Alberta were 20.3 million metric tons at the end of 1978 and 20.1 million tons at the end of 1979. The average market value of sulfur f.o.b. plant was $18.65 per metric ton in December 1978 and $29.15 per ton in December 1979.[5]

In 1979, scheduled exports of sulfur were disrupted early in the year due to delayed deliveries from plants and labor disputes at Vancouver. In October, the Second Narrows Bridge was damaged interrupting ship movements and causing rerouting of sulfur trains from Vancouver Wharves to Port Moody. An accident destroyed a railroad trestle in northern British Columbia. The interrupted railway link was bypassed by trucking sulfur around the break. Despite the problems, exports through Vancouver Wharves-Port Moody were greater than in 1978.

France.—Production of recovered elemental sulfur was estimated at 2.1 million tons in 1979. Exports were about 1.2 million tons.

Iraq.—In 1979 sulfur output at the Misraq mine was about 660,000 tons and production of recovered elemental sulfur from the Kirkuk natural gas plant was about 40,000 tons.

Japan.—Recovery of sulfur at petroleum refineries in 1979 was about 1.1 million metric tons.

Mexico.—In 1979, Frasch sulfur production by Azufrera Panamericana SA at Jaltipan and Cie. Exploradora de Istmo at Texistepic were about 2.0 million metric tons. Capacity to recover elemental sulfur by Pemex was increased to 300,000 tons.

Poland.—Sulfur production in 1978 was a record 5.4 million tons and exports were about 4.3 million tons, 60% to market economy countries.

Changes in the sulfur industry of Poland since 1968 were reviewed. Sulfur production rose from 1.3 million tons in 1968 to 5.4 million metric tons in 1978.[6]

U.S.S.R.—Consumption of sulfur, in 1978, was 9.3 million tons; 4.2 million tons of elemental sulfur, 2.8 million tons from pyrites, and 2.3 million tons in other forms, mainly smelter gas. The U.S.S.R. was a net importer of about 500,000 tons. The outlook was for increased sulfur production from the Orenburg gas processing plant, with capacity of 1 million tons, the Yavorov complex with 1.5 million tons capacity and the Astrakhan gas plant with expected capacity of 2 million tons of sulfur annually.[7]

Table 17.—Sulfur: World production in all forms, by country and source

(Thousand metric tons)

Country[1] and Source[2]	1976	1977	1978[p]	1979[e]
Algeria, byproduct, petroleum and natural gas	10	10	15	15
Argentina:				
Native (from caliche)	20	27	34	35
Byproduct, all sources	19	20	20	20
Total	39	47	54	55
Australia:[3]				
Pyrite[4]	108	108	67	70
Byproduct:				
Metallurgy[5]	[r]130	121	140	140
Petroleum	7	11	11	11
Total	[r]245	240	218	221
Austria:				
Byproduct:				
Metallurgy	8	8	9	10
Petroleum and natural gas	18	25	22	25
Gypsum	23	27	27	25
Total	49	60	58	60
Bahamas: Byproduct, petroleum	5	[e]5	[e]5	5
Bahrain: Byproduct, petroleum	10	7	25	25
Belgium: Byproduct, all sources[e]	[r]218	257	267	270
Bolivia:[7] Native[8]	15	6	15	15
Brazil:[3] [9] Byproduct, petroleum	30	44	54	55
Bulgaria:				
Pyrite[e]	280	305	310	315
Byproduct, all sources[e]	60	65	70	75
Total[e]	340	370	380	390
Canada:				
Pyrite	15	12	5	[10]16
Byproduct:				
Metallurgy	705	766	676	[10]605
Natural gas	[r]6,241	6,475	6,248	[10]5,935
Petroleum	200	160	200	200
Tar sands	100	100	118	[10]213
Total	[r]7,261	7,513	7,247	6,969
Chile:[7]				
Native:				
Refined	16	5	14	10
From caliche	2	27	18	20
Byproduct, metallurgy	30	29	30	30
Total	48	61	62	60
China:				
Mainland:				
Native[e]	[r]150	[r]170	200	200
Pyrite[e]	900	[r]1,000	1,100	1,200
Byproduct, all sources[e]	[r]300	[r]300	350	400
Total[e]	[r]1,350	[r]1,470	1,650	1,800
Taiwan:				
Native	5	8	5	5
Pyrite	4	3	3	3
Byproduct, all sources[e]	2	2	2	2
Total[e]	11	13	10	10
Colombia:				
Native	[r]24	22	18	20
Byproduct, petroleum	2	2	3	3
Total	[r]26	24	21	23
Cuba:				
Pyrite[e]	20	20	20	20
Byproduct, petroleum[e]	8	8	8	8
Total[e]	28	28	28	28
Cyprus:[11] Pyrite	95	81	63	65

See footnotes at end of table.

Table 17.—Sulfur: World production in all forms, by country and source —Continued

(Thousand metric tons)

Country[1] and Source[2]	1976	1977	1978[p]	1979[e]
Czechoslovakia:				
Native	12	5	5	5
Pyrite	50	55	60	60
Byproduct, all sources	10	9	10	10
Total	72	69	75	75
Denmark: Byproduct, petroleum	10	11	14	15
Ecuador:				
Native	[e]1	[e]1	1	1
Byproduct:				
Natural gas[e]	[r]5	[r]5	5	5
Petroleum[e]	[r]3	[r]3	5	5
Total[e]	9	9	11	11
Egypt:[3] [9] Byproduct, petroleum and natural gas	5	5	3	5
Finland:				
Pyrite	234	130	87	85
Byproduct:				
Metallurgy	[r]283	280	232	270
Petroleum[e]	25	25	30	30
Total	[r]542	435	349	385
France:				
Byproduct:				
Natural gas[12]	1,737	1,911	1,970	2,000
Petroleum[12]	88	89	90	90
Unspecified[13]	143	160	160	160
Total	1,968	2,160	2,220	2,250
German Democratic Republic:				
Pyrite[e]	10	10	10	10
Byproduct, all sources[e]	[r]329	340	350	350
Total[e]	[r]339	350	360	360
Germany, Federal Republic of:				
Pyrite	233	235	221	260
Byproduct:				
Metallurgy[14]	390	385	380	380
Natural gas[12]	460	631	650	650
Petroleum[12]	119	186	190	190
Unspecified[13]	161	165	160	160
Total	1,363	1,602	1,601	1,640
Greece:				
Pyrite	[r]81	58	62	75
Byproduct, petroleum[e]	3	3	3	3
Total[e]	[r]84	61	65	78
Hungary:				
Pyrite[e]	3	3	3	3
Byproduct, all sources	8	8	9	9
Total[e]	11	11	12	12
India:[3]				
Pyrite	19	14	20	15
Byproduct:				
Metallurgy[e]	111	117	115	115
Petroleum	7	7	7	7
Total[e]	137	138	142	137
Indonesia:[11] Native	3	[e]2	[e]2	2
Iran:				
Native[e]	[r]188	[r]188	150	75
Byproduct, petroleum and natural gas	[r]399	400	300	200
Total[e]	[r]587	[r]588	450	275

See footnotes at end of table.

Table 17.—Sulfur: World production in all forms, by country and source —Continued

(Thousand metric tons)

Country[1] and Source[2]	1976	1977	1978[p]	1979[e]
Iraq:				
Frasch	[r]582	620	600	660
Byproduct, petroleum and natural gas[e]	[r]40	40	40	40
Total[e]	622	660	640	700
Ireland: Pyrite	31	22	20	20
Israel: Byproduct, petroleum and natural gas	10	[e]10	[e]10	10
Italy:				
Native	35	36	16	16
Pyrite	[r]366	371	330	330
Byproduct, all sources[e] [15]	211	259	250	250
Total[e]	612	666	596	596
Japan:				
Pyrite	471	389	327	330
Byproduct:				
Metallurgy[16]	1,252	1,336	1,296	1,350
Petroleum[17]	925	1,100	1,104	1,100
Total	2,648	2,825	2,727	2,780
Korea, North:				
Pyrite[e]	245	250	255	255
Byproduct, metallurgy[e]	20	12	10	10
Total[e]	265	262	265	265
Korea, Republic of:				
Pyrite	(18)	--	--	--
Byproduct:				
Metallurgy[e]	22	25	25	25
Petroleum[e]	25	25	25	25
Total[e]	47	50	50	50
Kuwait: Byproduct, petroleum and natural gas	[r]61	79	100	100
Libya: Byproduct, petroleum and natural gas	20	20	20	20
Mexico:				
Frasch	2,054	1,723	1,818	1,960
Byproduct:				
Metallurgy[e]	75	80	100	100
Petroleum and natural gas	96	133	135	330
Total[e]	2,225	1,936	2,053	2,390
Morocco: Pyrite	23	45	61	60
Netherlands: Byproduct:				
Metallurgy[e]	[r]85	64	60	60
Petroleum[e]	65	64	65	65
Total[e]	[r]150	128	125	125
Netherlands Antilles: Byproduct, petroleum	95	94	95	95
New Zealand: Byproduct all sources	1	1	1	1
Norway:				
Pyrite	188	158	151	150
Byproduct:				
Metallurgy[e]	33	38	38	40
Petroleum[e]	7	7	6	6
Total	228	203	195	196
Pakistan:				
Native	1	1	1	1
Byproduct, all sources	12	12	14	14
Total	13	13	15	15
Peru:				
Native	1	1	(18)	1
Byproduct, all sources	16	20	18	20
Total	17	21	18	21
Philippines: Pyrite	77	50	51	55

See footnotes at end of table.

Table 17.—Sulfur: World production in all forms, by country and source —Continued

(Thousand metric tons)

Country[1] and Source[2]	1976	1977	1978[p]	1979[e]
Poland:[19]				
Frasch[e]	[r]4,341	[r]4,321	4,546	4,500
Native[e]	550	[r]450	505	500
Byproduct:				
Metallurgy[e][20]	239	314	315	315
Petroleum[e][20]	25	35	35	35
Gypsum[e]	55	30	20	20
Total[e]	[r]5,210	[r]5,150	5,421	5,370
Portugal:				
Pyrite	181	156	138	140
Byproduct, all sources	[r]1	2	1	2
Total	182	158	139	142
Rhodesia, Southern:				
Pyrite[e]	[r]40	[r]40	40	40
Byproduct: Coal and/or metallurgy[e]	5	5	5	5
Total[e]	[r]45	[r]45	45	45
Romania:				
Pyrite[e]	375	395	400	425
Byproduct, all sources[e]	98	110	120	130
Total[e]	473	505	520	555
Saudi Arabia: Byproduct petroleum and natural gas	3	3	3	125
Singapore: Byproduct, petroleum	[r]7	23	25	25
South Africa, Republic of:				
Pyrite	294	332	340	340
Byproduct:				
Metallurgy	91	105	100	100
Petroleum	27	28	25	25
Total	412	465	465	465
South-West Africa, Territory of (Namibia): Pyrite	4	4	4	4
Spain:				
Pyrite	[r]1,052	1,102	1,071	1,160
Byproduct:				
Metallurgy	123	129	117	120
Petroleum	4	5	10	10
Coal (lignite) gasification[e]	1	2	3	3
Total	1,180	1,238	1,201	1,293
Sweden:				
Pyrite	205	204	233	240
Byproduct:				
Metallurgy	[r]140	135	130	130
Unspecified[21]	[e]28	[e]30	[e]18	20
Total	373	369	381	390
Switzerland: Byproduct, all sources	2	2	3	3
Syria: Byproduct, petroleum and natural gas	5	[e]4	[e]6	6
Thailand: Byproduct, all sources	(22)	(22)	--	--
Trinidad and Tobago: Byproduct, petroleum[3]	55	55	54	55
Turkey:				
Native	21	20	28	30
Pyrite	38	18	90	90
Byproduct, all sources	69	80	80	80
Total	128	118	198	200
U.S.S.R.:				
Frasch[e]	[r]500	[r]500	800	800
Native[e]	[r]2,200	[r]2,400	2,700	2,700
Pyrite[e]	[r]3,300	[r]3,500	3,500	3,500
Byproduct:[e]				
Coal	40	[r]40	40	40
Metallurgy	[r]2,040	[r]2,180	2,210	2,210
Natural gas	[r]870	[r]920	1,100	1,100
Petroleum	[r]190	[r]200	200	200
Total[e]	[r]9,140	[r]9,740	10,550	10,550

See footnotes at end of table.

Table 17.—Sulfur: World production in all forms, by country and source —Continued

(Thousand metric tons)

Country[1] and Source[2]	1976	1977	1978[p]	1979[e]
United Kingdom:				
Byproduct:				
Metallurgy	37	61	47	50
Spent oxides	6	5	5	5
Unspecified	74	65	70	70
Total	117	131	122	125
United States:				
Frasch	6,365	5,916	5,648	[10]6,257
Pyrite	290	169	301	[10]400
Byproduct:				
Metallurgy	957	960	1,108	[10]1,167
Natural gas	1,298	1,426	1,753	[10]1,760
Petroleum	1,890	2,197	2,309	[10]2,310
Unspecified	78	59	61	[10]107
Total	10,878	10,727	11,175	[10]12,101
Uruguay: Byproduct, petroleum	2	2	2	2
Venezuela: Byproduct, petroleum and natural gas	90	95	95	95
Yugoslavia:				
Pyrite	[r]185	166	120	120
Byproduct:				
Metallurgy[e]	200	[r]200	200	200
Petroleum[e]	5	5	7	7
Total[e]	390	[r]371	327	327
Zaire: Byproduct, metallurgy	37	31	30	30
Zambia:				
Pyrite	9	8	6	6
Byproduct, all sources	91	87	109	110
Total	100	95	115	116
Grand total	[r]50,888	52,093	53,399	54,834
Of which:				
Frasch	[r]13,842	13,080	13,412	14,277
Native	[r]3,244	3,369	3,712	3,636
Pyrite	[r]9,426	9,413	9,469	9,862

See footnotes at end of table.

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Table 17.—Sulfur: World production in all forms, by country and source —Continued

(Thousand metric tons)

Country[1] and Source[2]	1976	1977	1978[p]	1979[e]
Byproduct:				
Coal and coal gasification	41	42	43	43
Metallurgy	[r]7,013	7,381	7,368	7,462
Natural gas	[r]10,611	11,368	11,726	11,450
Petroleum	[r]3,839	4,400	4,607	4,607
Tar sands	100	100	118	213
Petroleum and natural gas undifferentiated	[r]757	824	749	971
Spent oxides	6	5	5	5
Unspecified sources	[r]1,931	2,053	2,143	2,263
Gypsum	78	57	47	45

[e]Estimate. [p]Preliminary. [r]Revised.

[1] In addition to the countries listed, a number of nations may produce limited quantities of either elemental sulfur or compounds (chiefly H_2S or SO_2) as a byproduct of petroleum, natural gas, and/or metallurgical operations, but output, if any, is not quantitatively reported, and no basis is available for the formulation of reliable estimates of output. Countries not listed in this table which may recover byproduct sulfur from oil refining include: Albania, Bangladesh, Brunei, Burma, Costa Rica, Guatemala, Honduras, Jamaica, Malaysia, Nicaragua, Paraguay, and People's Democratic Republic of Yemen. Albania and Burma may also produce byproduct sulfur from crude oil and natural gas extraction. No complete listing of other nations which may produce byproduct sulfur from metallurgical operations (including processing of coal for metallurgical use) can be compiled, but the total of such output is considered as small. Nations listed in the table which may have production from sources other than those listed are identified by individual footnotes.

[2] The term "source" reflects both the means of collecting sulfur and the type of raw material. Sources listed include the following: (1) Frasch recovery; (2) native, comprising all production of elemental sulfur by traditional mining methods (thereby excluding Frasch); (3) pyrite (whether or not the sulfur is recovered in the elemental form or as acid); (4) byproduct recovery, either as elemental sulfur or as sulfur compounds from coal gasification, metallurgical operations including associated coal processing, crude oil and natural gas extraction, petroleum refining, tar sand cleaning, and processing of spent oxide from stack-gas scrubbers; and (5) recovery from the processing of mined gypsum. Recovery of sulfur in the form of sulfuric acid from artificial gypsum produced as a byproduct of phosphatic fertilizer production is excluded because to include it would result in double counting. It should be noted that production of Frasch sulfur, other native sulfur, pyrite derived sulfur, mined gypsum derived sulfur, byproduct sulfur from extraction of crude oil and natural gas, and recovery from tar sands are all credited to the country of origin of the extracted raw material; in contrast, byproduct recovery from metallurgical operations, petroleum refineries, and spent oxides are credited to the nation where the recovery takes place, which in some instances is not the original source country of the crude product from which the sulfur is extracted.

[3] In addition may produce limited quantities of byproduct sulfur from natural gas.

[4] Excluding sulfur content of auriferous pyrites, for which data are not available.

[5] Excluding sulfur recovered, if any, from processing copper concentrates.

[6] Includes the following quantities recovered in elemental form in thousand metric tons: 1976—60; 1977-79—not available.

[7] In addition, may produce limited quantities of byproduct sulfur from crude oil and natural gas and/or from petroleum refining.

[8] Exports; regarded as tantamount to production owing to minimal domestic consumption levels.

[9] In addition, may produce limited quantities of byproduct sulfur from metallurgical operations and/or coal processing.

[10] Reported figure.

[11] In addition, may produce limited quantities of byproduct sulfur from oil refining.

[12] Elemental byproduct recovered sulfur only; sulfur recovered as SO_2, H_2S, and/or other compounds are included under unspecified.

[13] Comprises all byproduct sulfur recovered in the form of compounds including that, if any, recovered from petroleum and natural gas operations, as well as total recovery from metallurgical operations.

[14] Includes only the elemental sulfur equivalent of sulfuric acid produced as a byproduct from metallurgical furnaces; additional output may be included under undifferentiated.

[15] Includes recovery from gypsum, if any.

[16] Presumably includes sulfur recovered from coal processed to coke at metallurgical facilities, and excludes sulfur, if any, recovered by metallurgical facilities in elemental form.

[17] Includes sulfur recovered in the form of acid from coal, heavy oil and other unspecified sources, as well as sulfur, if any, recovered by metallurgical facilities in elemental form.

[18] Less than 1/2 unit.

[19] Official Polish sources report total mined elemental sulfur output annually; this figure has been divided between Frasch and other native sulfur on the basis of information obtained from supplementary sources. Therefore, although both numbers are estimates, the total is not an estimate. Estimates for production of byproduct and gypsum-derived sulfur are based on officially published data on sulfuric acid production and additional information from unofficial sources.

[20] Estimates reported under "Metallurgy" represent byproduct recovery in the form of compounds (principally sulfuric acid) from all sources (including coal and fertilizer plants); estimates reported under "Petroleum" represent only elemental sulfur recovery from petroleum, with any recovery in the form of compounds included under "Metallurgy."

[21] Elemental sulfur only.

[22] Revised to zero.

TECHNOLOGY

Analyses were made of wet and dry sulfur forming processes to evaluate both the quality of the resulting sulfur product and the economic practicability of the processes.[8]

Shipping and storage of molten sulfur is both practical and economic. The temperature of all equipment must be maintained between 115å and 155å C. Molten sulfur can be shipped by truck, rail car, barge, ship, or pipeline.[9]

The Federal Bureau of Mines operated a citrate-process pilot plant to study flue gas desulfurization from industrial waste gases.[10] During citrate-process development, research was also carried out to detect and analyze reaction products in the support of laboratory and pilot plant tests and to insure safety in the experimental environment.[11] A flue gas desulfurization demonstration plant was designed to use the citrate process in the removal of sulfur dioxide from George F. Wheaton coal burning powerplant at Monaca, Pa.[12] The demonstration plant was completed in April 1979 for a 1-year demonstration.

Sulfur may play a key role in the high level of volcanic activity on Io, the innermost of Jupiter's four big Galilean satellites according to a theory developed from data gathered during Voyager I flyby of Jupiter in March 1979.[13]

The requirement to remove sulfur oxides from flue gas for meeting environmental control legislation and regulations has resulted in numerous processes to reduce sulfur emissions. Several of these processes were described and evaluated.[14]

An alternative to treating waste gases with low concentrations of hydrogen sulfide is to oxidize the gas to yield sulfur dioxide and to convert that to sulfuric acid.[15]

Evolution of sulfur melting and burning over the last 15 years was described.[16]

With the growing potential for shipments of sulfur in the dry form, various processes have been developed to provide a form of sulfur that would be dust free. The processes were reviewed and the advantages and problems evaluated.[17]

Use of water as a heat exchange medium in energy recovery has some limitations at high temperatures. Using sulfur in a binary cycle at high temperatures increases energy recovery.[18]

Paving materials have been developed in which sulfur replaces up to 50% of the asphalt normally present and which can be prepared and placed with existing mixing and paving equipment.[19] Two approaches to incorporating sulfur in asphalt were reported; one consists of conventional asphalt binder and a sulfur-sand aggregate and the other uses an emulsion of sulfur in asphalt as a binder in conjunction with regular high-grade aggregate.[20]

The manufacture, characteristics, use, and current technologies in sulfur to bind aggregates and produce composites for a variety of applications was discussed.[21]

The Federal Bureau of Mines has developed sulfur concretes that are more resistant to deterioration in acid and salt corrosive environments than portland cement concretes.[22] Results of these developments were described to industry representatives at a Bureau of Mines-Sulphur Institute Technology Transfer Symposium March 15-16, 1979, at the Boulder City, Nev., Research Laboratory. Evaluation of sulfur concretes as flooring and chemical tanks was discussed. Other research was reported on the use of sulfur concrete for concrete blocks, pipes, and curbing at several locations on the Arabian Peninsula and in Canada.[23]

Preliminary results were described on a process to coat urea with sulfur to slow down release of nitrogen nutrient.[24]

Sulfur additions to soil serves as a plant nutrient and enables plants to better utilize nitrogen, phosphate, and potash.[25] Biochemical, ecological and physiological investigations were made of sulfur bacteria for biological estimation of pollution.[26] Properties, occurrences, uses, and biochemical aspects of hydrogen sulfide were discussed as part of a series on medical and biological effects of environmental pollutants.[27]

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[illegible]

[illegible] play a key role in the high level of [illegible] activity [illegible]

[illegible]

Evaluation of sulfur [illegible] and [illegible] over the last [illegible] years was [illegible].

With the growing potential for shipment of sulfur in the dry form, various processes have been developed to provide a form of sulfur that would be dust free. The processes were reviewed and the advantages and problems discussed.

Use of water as a heat exchange medium in energy recovery has some limitations at high temperatures. Using sulfur in a binary cycle at high temperatures to [illegible] energy recovery.

Paving materials have been developed in which sulfur replaces up to [illegible] of the asphalt normally present and which can be prepared and placed with existing mixing and paving equipment. Other approaches to incorporating sulfur in asphalt were pre-

[illegible]

Talc and Pyrophyllite

By Robert A. Clifton[1]

Increasing demand for talc and pyrophyllite in the domestic market led to an increase in the combined total domestic production of these commodities for 1979. Production of talc set a new record high in 1978, and the 1979 production was approximately the same. Pyrophyllite production increased both years. The value of crude talc and pyrophyllite produced increased significantly during the 2-year period.

Table 1 shows the increases in total sales of crude and processed talc and pyrophyllite in quantity and value. Apparent domestic consumption increased during both years. Exports were down in 1978 and up in 1979 from those of previous years, but 1979 tonnages were below those of 1977. The value of exported talc rose for both 1978-79.

Continental Minerals Corp. of Las Vegas, Nev., began production of talc from its newly optioned property in Death Valley, Calif., in 1978. The acquisition of the former Grantham property included mills in Dunn Siding and Los Angeles, Calif.

Legislation and Government Programs.—In 1978, the National Institute of Occupational Safety and Health (NIOSH) contracted with Stanford Research Institute (SRI) to draft a document for later publica-

Table 1.—Salient talc and pyrophyllite statistics

(Thousand short tons and thousand dollars)

	1975	1976	1977	1978	1979
United States:					
Mine production, crude:					
Talc	873	W	1,099	1,268	1,268
Pyrophyllite	92	W	106	116	185
Total	965	1,092	1,205	1,384	1,453
Value:					
Talc	$7,454	$9,542	$12,524	$14,956	$19,365
Pyrophyllite	1,475	360	561	811	998
Total	8,929	9,902	13,085	15,767	20,364
Sold by producers, crude and processed:					
Talc	845	794	996	1,155	1,119
Pyrophyllite	86	107	118	116	195
Total	931	901	1,114	1,271	1,314
Value:					
Talc	$16,496	$33,014	$50,647	$68,781	$80,529
Pyrophyllite	1,379	934	1,708	2,804	4,413
Total	17,875	33,948	52,355	71,585	84,942
Exports[1]	158	212	322	267	316
Value	$6,338	$9,034	$9,166	$12,359	$15,210
Imports for consumption	23	20	22	19	22
Value	$1,471	$1,861	$2,094	$1,946	$2,822
Apparent consumption	796	709	814	1,023	1,020
World: Production	5,403	[r]5,806	[r]6,200	6,475	6,850

[r] Revised. W Withheld to avoid disclosing company proprietary data.
[1] Excludes powders—talcum (in package), face, and compact.

tion entitled "Criteria Document for Exposure to Talc." The original draft was severely criticized by the talc industry when it was circulated for review late in the year. The document was not published in 1979.

The national stockpile inventory of steatite, block or lump, was at a reported 1,092 short tons at the end of 1979. This still far exceeded the goal of 104 tons. The ground steatite inventory, with a goal of zero, was at 1,089 tons.

The allowable depletion rates established under the Tax Reform Act of 1969 remained at 22% for domestic block steatite and 14% for foreign through 1979.

Tariff rates on imported talc minerals follow: Crude and unground, 0.02 cents per pound; ground, washed, powdered and/or pulverized, 6% ad valorem; cut, sawed, or in blanks, crayons, cubes, disks or other forms, 0.2 cents per pound; other not specifically provided for, 12% ad valorem.

DOMESTIC PRODUCTION

Talc.—Production from U.S. talc mines rose during 1978-79 and exceeded that in the former record year, 1974. The value of mine production established another record high each year.

Talc, including soapstone, was produced at 37 mines in 12 States in 1978, and 36 in the same States in 1979. California's 12 mines were by far the largest number for any State in both years. Mines in four States produced better than three-quarters of the tonnage and two-thirds of the value of talc in 1978-79. The States producing the highest tonnage in decreasing order were Vermont, Montana, Texas, and New York. California led all States in the value of the talc produced. Of the talc-producing States, only Nevada had no milling facilities.

The seven largest domestic producers of talc in 1978-79, listed alphabetically, were Cyprus Industrial Minerals Co., with mines in California, Montana, and Texas; Eastern Magnesia Talc Co. in Vermont; Pfizer Inc., Minerals, Pigments & Metals Div., in California and Montana; Southern Clay Products, Inc., in Texas; R. T. Vanderbilt Co., Inc., in New York; Western Minerals, Inc., in Texas; and Windsor Minerals, Inc., in Vermont.

Pyrophyllite.—The pyrophyllite-producing mines of the United States were in North Carolina and California. The increase in production put the total at the highest level ever. Six companies operated seven mines during the period.

Table 2.—Talc and pyrophyllite produced in the United States, by State

(Thousand short tons and thousand dollars)

State	1978		1979	
	Quantity	Value	Quantity	Value
California (talc and pyrophyllite)	106	3,795	176	6,960
Georgia (talc)	22	89	29	117
Montana (talc)	319	5,512	343	5,940
North Carolina[1]	116	811	128	667
Texas (talc)	288	1,520	207	1,544
Vermont (talc)	315	2,238	346	2,755
Other States[2] (talc)	218	1,802	224	2,381
Total	1,384	15,767	1,453	20,364

[1] Talc and pyrophyllite produced, pyrophyllite only reported.

[2] Includes Arkansas, Iowa, Nevada, New York, North Carolina, Oregon, and Virginia.

CONSUMPTION AND USES

The apparent domestic consumption of talc and pyrophyllite increased in 1978-79 and was the approximate equal of the 1973 record. The sales value of talc and pyrophyllite both set new record highs.

The 1978-79 end use distribution, with 1979 data in parentheses, showed 28% (27%) of the ground talc used in ceramics, 21% (25%) in paint, 16% (12%) in plastics, and 9% (11%) in paper, and for both years 8% in cosmetics, 4% in rubber, 2% in roofing, 1% each in insecticides and refractories, with the remainder going to other uses.

The largest portion, 35% (30%), of the pyrophyllite was used in refractories, 24% (17%) was used in insecticides, 15% (34%) in ceramics, 10% (7%) in roofing, and 16% (12%) in other uses.

Table 3.—End uses for ground talc and pyrophyllite

(Thousand short tons)

Use	1978			1979		
	Talc	Pyrophyllite	Total[1]	Talc	Pyrophyllite	Total[1]
Ceramics	257	17	274	260	63	323
Cosmetics[2]	69	--	69	74	--	74
Insecticides	13	27	40	13	32	46
Paint	192	1	193	237	1	238
Paper	87	--	87	105	--	105
Plastics	147	1	148	112	1	113
Refractories	6	39	45	6	56	62
Roofing	18	11	28	19	13	32
Rubber	36	1	37	39	--	40
Other uses[3]	92	16	109	95	21	115
Total[1]	917	112	1,029	960	188	1,148

[1] Data may not add to totals shown because of independent rounding.

[2] Incomplete data. Some cosmetic talc known to be included in "Other uses."

[3] Includes art sculpture, asphalt filler, crayons, floor tile, foundry facings, rice polishing, stucco, and other uses not specified.

PRICES

Depending on quality and degree and method of processing, talc prices vary over a wide range. In general, prices rose during the 1978-79 period. Engineering and Mining Journal, December 1979, quoted prices for domestic talc, ground, in carload lots, f.o.b. mine or mill, containers included, per short ton, as follows:

Vermont:	
98% through 325 mesh, bulk	$64.00
99.99% through 325 mesh, bags:	
Dry processed	108.00
Water beneficiated	$176.00-189.00
New York:	
96% through 200 mesh	43.00- 46.00
98% to 99.25% through 325 mesh	50.00- 68.00
100% through 325 mesh, fluid-energy ground	114.00
California:	
Standard	69.50
Fractionated	37.00- 71.00
Micronized	62.00-104.00
Cosmetic steatite	44.00- 65.00
Georgia:	
98% through 200 mesh	24.20
99% through 325 mesh	35.00
100% through 325 mesh, fluid-energy ground	85.00

American Paint & Coatings Journal, December 24, 1979, listed the following prices per ton for paint-grade talcs in carload lots:

California:	
Bags, mill:	
White, Hegman No. 3-3-1/2	$93.00
Hegman No. 4-5	119.00
Montana: Ultrafine grind, f.o.b. mill	135.00
New York:	
Nonfibrous, bags, mill:	
98% through 325 mesh	$46.50- 50.50
99.4% through 325 mesh	55.50
Trace retained on 325 mesh	105.00
Fine micron talcs (origin not specified)	144.00

The approximate equivalents, in dollars per short ton, of the price ranges quoted in Industrial Minerals (London), December 1979, for steatite talc, c.i.f. main European ports, were as follows:

Australian, cosmetic (ex store)	$231-$242
Norwegian:	
Ground (ex store)	121- 154
Micronized (ex store)	178- 249
French, fine-ground	231- 253
Italian, cosmetic-grade	320
Chinese, normal (ex store):	
UK 200 mesh	242- 253
UK 300 mesh	253- 264

FOREIGN TRADE

Exports.—There was a 17% decrease in talc exports during 1978, followed by a 46% increase in 1979. The loss in tonnage in 1978 and gain in 1979 left the exports at the third and second, respectively, highest levels ever. However, the value of exported talc rose 35% and averaged $46 per ton in 1978 and another 23% in 1979, while averaging $48 per ton. The great decrease in the quantity of lower priced talc exported to Canada in 1978 was a major factor in the higher export unit value, as well as the decrease in total exports.

Mexico was the major importer of U.S. talc in 1978-79 followed by Canada, Japan, and Belgium. A total of 63 countries imported U.S. talc in 1978.

The growth rate of the dollars received for exported talc over the past 10 years has averaged nearly 5%, and the projected value over the next 20 years would total well over $400 million.

Imports.—U.S. imports of talc decreased 13% in 1978, and increased 16% in 1979. The average value of imports was $101 per ton in 1978 and $126 in 1979. The cosmetic grades accounted for the high prices. Italy, with 50% for both years, was the leading source of imported talc, followed by France and Canada.

Table 4.—Recipients of exported U.S. talc

Country	1977			1978			1979		
	Percent of U.S. exports		Value per short ton[1]	Percent of U.S. exports		Value per short ton[1]	Percent of U.S. exports		Value per short ton[1]
	Quantity	Value		Quantity	Value		Quantity	Value	
Belgium-Luxembourg	6	8	$36	8	8	$50	6	7	$58
Canada	41	31	21	21	30	68	19	29	75
Japan	6	9	46	7	11	69	6	8	59
Mexico	39	20	15	50	18	17	52	23	22
Other	8	32	112	14	33	104	17	33	91
Total	--	--	28	--	--	46	--	--	48

[1] Customs declaration.

Table 5.—U.S. exports of talc

(Thousand short tons and thousand dollars)

Year	Quantity	Value
1976	212	9,084
1977	322	9,166
1978	267	12,359
1979	316	15,210

Table 6.—U.S. imports for consumption of talc, by class and country

Year and country	Crude and unground		Ground, washed, powdered, or pulverized		Cut and sawed		Total unmanufactured	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value[1] (thousands)
1976	14,814	$1,023	4,540	$357	717	$481	20,071	$1,861
1977:								
Canada	--	--	6,760	391	5	2	6,765	393
France	4,537	159	595	58	--	--	5,182	217
Italy	8,047	739	290	58	--	--	8,337	797
Japan	--	--	8	4	435	346	443	350
Korea, Republic of	--	--	729	85	264	149	993	234
Other[2]	25	2	300	60	92	41	420	103
Total	12,612	900	8,682	656	796	538	22,090	2,094
1978:								
Canada	15	5	2,196	147	4	2	2,215	154
France	5,114	209	407	53	--	--	5,521	262
Italy	9,039	879	653	59	--	--	9,692	938
Japan	--	--	16	10	294	276	310	286
Korea, Republic of	--	--	937	118	506	164	1,443	277
Other[3]	32	4	103	22	3	3	138	29
Total	14,200	1,097	4,312	404	807	445	19,319	1,946
1979:								
Canada	3	2	2,161	144	148	76	2,312	222
France	3,971	203	461	67	--	--	4,432	270
Italy	11,460	1,276	359	88	--	--	11,819	1,354
Japan	([4])	([4])	17	12	389	532	406	544
Korea, Republic of	57	5	517	88	327	102	901	195
Other[5]	2,417	169	50	4	37	54	2,504	227
Total	17,908	1,655	3,565	403	901	764	22,374	2,822

[1] Does not include talc, n.s.p.f.; 1976—$302,455; 1977—$593,240; 1978—$784,877; 1979—$1,291,043.

[2] Includes Belgium-Luxembourg, China (Mainland only), the Dominican Republic, Hong Kong, India, Israel, and Nepal.

[3] Includes Botswana, Chile, China (Mainland and Taiwan), Egypt, the Federal Republic of Germany, Hong Kong, India, Ireland, Israel, Kenya, Lesotho, Mexico, Singapore, the Republic of South Africa, Spain, Uganda, the United Kingdom, and the U.S.S.R.

[4] Less than 1/2 unit.

[5] Includes Australia, Austria, Belgium-Luxembourg, China (Mainland and Taiwan), the Federal Republic of Germany, India, Mexico, Morocco, Spain, and the United Kingdom.

WORLD REVIEW

Australia.—In 1979, Western Mining Corp. acquired a new partner in its Three Springs Talc Pty. Ltd. (TST) property, making Kalgoorlie Southern Gold Mines NL a half owner of the talc operation. The corporation reported production of 75,000 tons of talc in 1978 and announced acquisition of an adjacent property having in excess of 100,000 tons of salable talc. Although pyrophyllite production was fairly stable, Australian talc production more than doubled (at a 6.35% growth rate) between 1974 and 1978. Steetley Industries, Ltd., acquired the Pyrophyllite Corp. Ltd. in 1978.

Brazil.—Cie. de Mokta of the French group Imetal plans to exploit some talc deposits in Minas Gerais.

Canada.—Steetley Talc Co., a wholly owned subsidiary of the Steetley Co. of the United Kingdom purchased the Johns-Manville Corp. talc mine and processing facilities near Timmins, Ontario. Steetley began flotation separation of the talc at the mine with final grinding in Timmins early in 1979 at a 25,000-ton-per-year capacity and appointed the R. T. Vanderbilt Co., Inc., as its exclusive U.S. sales agent.

Finland.—The new Oy Lohja A. B. talc company joined the other Finnish talc producer, Yhtyneet Paperitehtaat Oy in a new sales company, Finnminerals, in 1978, to market their talcs domestically and internationally. The hope is that, with a total production of 480,000 tons per year, Finland will become Europe's largest talc exporter. ECC International, England's and the world's largest producer and exporter of china clays, has established a sales company in Finland, ECC International Oy to minimize the talc inroads into the clays paper markets.

Table 7.—Talc and pyrophyllite: World production, by country

(Short tons)

Country[1]	1976	1977	1978[p]	1979[e]
North America:				
Canada (shipments)	[r]75,876	79,807	67,970	[2]97,000
Mexico	212	180	2,909	3,000
United States	1,092,433	1,204,835	1,324,686	[2]1,452,733
South America:				
Argentina (talc and pyrophyllite)	59,698	59,804	52,504	60,000
Brazil (talc and pyrophyllite)[3]	[r]235,727	279,857	265,100	281,000
Chile	[r]142	471	476	480
Colombia	[e]1,100	1,268	1,455	1,400
Paraguay	[r]154	143	176	180
Peru (talc and pyrophyllite)	[r]16,050	16,535	14,234	16,500
Uruguay	1,398	1,829	[e]1,900	2,000
Europe:				
Austria (unground talc)	[r]110,945	114,366	117,780	120,000
Finland	[r]163,727	172,604	215,126	220,000
France (ground talc)	[r]281,970	315,811	334,542	335,000
Germany, Federal Republic of (marketable)	20,152	17,605	17,026	17,000
Greece (steatite)	6,110	--	1,188	--
Hungary[e]	17,600	17,600	19,000	19,000
Italy (talc and steatite)	169,575	179,056	193,077	192,900
Norway	130,305	108,122	[e]121,000	121,000
Portugal	[r]1,659	1,775	1,521	1,500
Romania[e]	66,000	66,000	66,000	66,000
Spain	52,489	[e]55,000	61,000	55,000
Sweden	[r]22,533	23,384	[e]26,000	24,000
U.S.S.R.[e]	485,000	500,000	520,000	530,000
United Kingdom	[r]16,314	16,535	19,842	20,000
Africa:				
Angola[e]	[r]55	([4])	--	--
Botswana	[5]159	317	345	330
Egypt	6,213	7,708	6,509	7,000
Ethiopia[e]	([4])	([4])	--	--
South Africa, Republic of[6]	14,135	14,554	13,940	[2]10,418
Sudan[e]	([4])	([4])	--	--
Zambia	117	[e]110	[e]110	--
Asia:				
Afghanistan[7]	9,574	6,295	1,957	550
Burma	[r]262	222	431	400
China:				
Mainland[e]	[r]165,000	[r]165,000	165,000	165,000
Taiwan	17,065	11,200	10,964	10,000
India	[r]280,240	310,431	339,786	350,000
Japan[8]	1,482,875	1,497,990	1,402,000	1,575,000
Korea, North[e]	140,000	140,000	140,000	140,000
Korea, Republic of (talc and pyrophyllite)	547,262	667,151	733,128	750,000
Nepal[9]	[r]57	85	562	560
Pakistan (pyrophyllite)	[r]5,550	10,118	27,877	30,000
Philippines	[r]1,555	1,323	4,476	5,000
Thailand (talc and pyrophyllite)	7,228	11,429	16,411	[2]14,927
Oceania: Australia	[r]101,519	123,778	167,125	155,000
Total	[r]5,806,035	6,200,298	6,475,188	6,849,878

[e]Estimate. [p]Preliminary. [r]Revised.

[1] In addition to the countries listed, Southern Rhodesia is believed to produce talc, but available information is inadequate to make reliable estimates.

[2] Reported figure.

[3] Total of beneficiated and salable direct shipping production of talc and pyrophyllite.

[4] Revised to zero.

[5] Exports.

[6] Includes talc and wonderstone.

[7] Data are for calendar year beginning March 20 of that stated.

[8] Includes talc and pyrophyllite; in addition pyrophyllite clay is produced; output was as follows in short tons: 1976 (revised) 497,911; 1977 (revised) 485,248; 1978, 467,379; 1979 (estimated) 480,000.

[9] Data based on Nepalese fiscal year, beginning mid July of year stated.

France.—Société des Talcs de Luzenac, with another acquisition, has added to its position of the largest talc producer among the market economy countries. The acquisition per year was Italy's Industria Mineraria Valle Sphurga whose 15,000 tons is 10% of that country's production. Luzenac now controls about 415,000 tons per year of capacity and, in 1979, opened a new management, research and development, and marketing office in Toulouse.

Germany, Federal Republic of.—Bavaria is the source of all of the so-called steatite and talc schists produced in the Federal Republic of Germany. Rosenthal Technik with 8,000 tons yearly and Johannes Scheruhn GmbH and Co. with a 6,000-ton yearly capacity are the principal steatite producers. Imports of over 100,000 tons per year have resulted in a 39% decrease in production since 1974.

India.—Anticipating government assistance by improvement of mine to railhead roads and rail facilities to the port of Bombay, the Golcha Group's Udaipur Mineral Development Syndicate Private Ltd. has ordered additional heavy mining machinery to raise production levels at its Ghewaria talc mines, Bhilwara District, Rajasthan. New production goals are 100,000 tons per year, up from 30,000. Rajasthan produced 86% of India's talc in 1977.[2]

Korea, Republic of.—Data released by the government's Korea Mining Promotion Corp. indicate a rosy future for that country's talc and pyrophyllite industries. Production data for talc for the years 1970 through 1976 show a sustained growth rate that averaged above 8%. Projections through 1981 foresee a slightly higher growth rate. Pyrophyllite production data for the same years show a phenomenal growth rate exceeding 15%. Projections foresee little change in that rate through 1981.

TECHNOLOGY

Americ Mines, Ltd., of Canada, which had purchased world rights to a process for making an inexpensive home insulating material from talc, has reported emergence of several products from its continuing efforts. It is projected that a plant to make loose fill insulation will be the first one onstream.

A General Motors Corp. researcher has suggested in an environmental publication that fly ash, a present air contaminant, could be used as a talc substitute.[3] He says that not only does it have similar composition to talc, but fly ash, being black, could be used as a polypropylene filler without the addition of carbon black.

The advantages of using talc on ceramic bodies were detailed in an industry magazine:[4] (1) It is a cheap source of MgO which acts as a flux. (2) It imparts to them a high thermal shock, high electrical resistance at elevated temperatures, and low dialectric loss and low power factor. (3) It has high specific heat and high resistance to acid attack. (4) In low-temperature bodies it increases thermal expansion. (5) In both high- and low-temperature bodies it decreases expansion.

The increased awareness of the energy imbalance in the United States has led the transportation industry, spurred by Congress and the administration, to search for lighter weight materials with which to manufacture vehicles. Plastics are a partial solution, and a phenomenal rise in their use is predicted for the near future. Most plastics, however, have a petrochemical base, so that the energy tradeoff is not complete. Realization, however, that up to 40% of the plastics' weight could be saved by use of fillers or extenders without sacrifice in essential characteristics helped in this respect. Some of the fillers (talc included) even increase some of the desired physical characteristics of the plastic.

The amount of plastics used would be further reduced by reinforcing agents to impart extra strength to the plastic matrix. Talc is unique in this respect among the fillers because of the platy nature of the mineral and the transverse strength across the plates.

A third desirable characteristic of the fillers is that the molten plastic be able to "wet" the particle surfaces with sufficient ease to make mixing easy. Talc has this characteristic, and some Death Valley talc is reportedly superior to any other for use with polypropylene.

Most talcs have superior color qualities, also, though this is less a factor in filler selection.

The whole subject of fillers for plastics is covered in depth in a recent publication.[5] In the introduction section, talc is shown to be an integral part of the expected boom in plastics. If that prediction is correct, and the use of talc in plastics exceeds an average growth rate of 11%, then the cumulative demand for this use alone would exceed 18 million short tons by the year 2000.

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Thorium

By William S. Kirk[1]

Monazite, the principal source of thorium, continued to be recovered as a byproduct at two locations in Florida throughout 1978 and most of 1979. However, most of the thorium compounds used by the domestic industry during 1978 and 1979 came from imports or existing company stocks.

No major developments occurred in the nonenergy uses of thorium, which include mantles for incandescent lamps, hardeners in magnesium alloys, refractories, welding rods, and electronics.

The only commercial thorium-fueled, high-temperature, gas-cooled reactor (HTGR) located at Fort St. Vrain, Colo., with a capacity of 330 megawatts, continued to run at 70% capacity in 1978 and 1979. The experimental thorium-fueled, light-water breeder reactor (LWBR) at Shippingport, Pa., continued to operate in 1978 and 1979.

The U.S. Geological Survey, assisted by the Bureau of Mines, completed its U.S. Department of Energy (DOE) sponsored thorium resources evaluation program in 1979.

Legislation and Government Programs.—The Tokyo round of negotiations was completed in 1979 resulting in new tariff agreements for minerals, including thorium, with the developed nations of the world. The agreements placed most nations on a most-favored-nation basis with generally lower rates to be phased in, or staged, over an 8-year period beginning January 1, 1980.

DOMESTIC PRODUCTION

Exploration.—The U.S. Geological Survey, in cooperation with the Bureau of Mines, concluded a study of the thorium resources of the United States.[2] The resulting paper, prepared on behalf of DOE, is the first definitive study of these resources in the United States. Thorium resources, in the higher grade and better known deposits, were assessed in (1) veins, (2) massive carbonatites, (3) stream placers of North Carolina and South Carolina, and (4) disseminated deposits. Thorium resources for the first three categories were divided into reserves and probable potential resources. These were then separated into the following cost categories: (1) the amount of ThO_2 producible at less than $15 per pound, (2) the amount producible at between $15 and $30 per pound, and (3) the amount producible at between $30 and $50 per pound. The type of mining and milling needed at each deposit determines the capital, operating, and fixed costs of both mining and milling. Costs start with the clearing of land and are carried through to the final product, which for all deposits is ThO_2.

The Bureau of Mines published a report describing three cost estimating models developed as guides for assigning costs to the recovery of thorium from domestic deposits.[3] These models have been used by the Geological Survey and DOE in evaluating the principal thorium resources of the United States.

The engineering and cost models were developed for the recovery of thorium contained in vein deposits, fluviatile placer deposits, and massive carbonatile deposits. The models can be used to determine the capital investment and operating expense required to mine and beneficiate thorium-containing ores from individual deposits. This cost, based on state-of-the-art mine and metal technology, is adjusted for variation in the grade, depth, and shape of the ore body and desired rate of production.

The Geological Survey also published a paper describing the geology and mineral

Table 1.—Companies with thorium processing and fabricating capacity

Company	Plant location	Operations and products
Atomergic Chemetals Corp	Plainview, N.Y.	Processes oxide, fluoride, and metal.
Babcock & Wilcox Co	Apollo, Pa.	Nuclear fuels.
Do	Leechburg, Pa	Do.
Do	Lynchburg, Va	Do.
Bettis Atomic Power Laboratory	West Mifflin, Pa	Nuclear fuels, Government research and development.
Cerac, Inc	Milwaukee, Wis	Processes compounds.
Ceradyne, Inc	Santa Anna, Calif	Processes oxide.
Consolidated Aluminum Corp	Madison, Ill	Magnesium-thorium alloy.
Controlled Castings Corp	Plainview, N.Y.	Do.
General Atomic Co	San Diego, Calif	Nuclear fuels.
General Electric Co	San Jose, Calif	Do.
Do	Wilmington, N.C.	Do.
W. R. Grace & Co	Chattanooga, Tenn	Processes domestic and imported monazite; stocks thorium-containing residues.
Hitchcock Industries, Inc	South Bloomington, Minn	Magnesium-thorium alloys.
Kerr-McGee Chemical Corp	Cimarron, Okla	Nuclear fuels.
Tennessee Nuclear Specialities, Inc	Jonesboro, Tenn	Processes oxide.
Union Carbide Corp., Nuclear Div	Oak Ridge, Tenn	Nuclear fuels, test quantities.
Ventron Corp., Alfa Div	Danvers, Mass	Metallic thorium.
Wellman Dynamics Corp	Creston, Iowa	Magnesium-thorium alloys.
Westinghouse Electric Corp	Bloomfield, N.J	Processes compounds; produces metallic thorium.
Do	Columbia, S.C	Nuclear fuels.

resources of the Lemhi Pass thorium district with a section on the description of selected thorium veins.[4] The district encompasses about 55 square miles and lies astride the Continental Divide in Idaho and Montana. Approximately 250 veins were mapped, 87% of which were thorium veins. The ThO_2 content of 420 samples from this district ranges from 0.0008% to 9.4%. The indicated thorium resources in the district are 176,500 short tons of ThO_2; the inferred resources are 128,900 short tons of ThO_2.

The U.S. Forest Service issued an Environmental Assessment Report on an application to prospect for uranium and thorium on 61,000 acres of White Mountain National Forest.[5]

Mine Production.—Titanium Enterprises closed dredging operations of its Green Cove Springs mine in 1978. The company continued to reprocess tailings to extract monazite, zircon and staurolite in 1978 and 1979. Production of monazite increased sharply in 1978 over the 1977 level, but declined somewhat in 1979. Humphreys Mining Co. recovered monazite from heavy-mineral beach sand. Humphreys dredging operation was located near Hilliard, Fla., and the wet, heavy concentrates were trucked to the company's drying plant at Folkston, Ga., for processing. Monazite production increased significantly during 1978. Humphreys shut down its mining and processing operations at the end of 1979 because the ore body had been depleted; consequently monazite production fell considerably. After extraction of rare earths from monazite, residues containing thorium were stored for future use.

Refinery Production.—During 1978-79, the only domestic firm with facilities for processing large tonnages of monazite was W. R. Grace & Co., Davison Chemical Div., at Chattanooga, Tenn. Although W. R. Grace did not produce any thorium compounds from monazite for sale, thorium was extracted from monazite during the refining of rare-earth elements and stored.

CONSUMPTION AND USES

Based on imports, sales from the national stockpile and other data, the estimated domestic consumption of thorium (in ThO_2 equivalence) was about 38 tons in 1978 and 36 tons in 1979. Nonenergy uses consumed about 34 tons of ThO_2 in 1978. The major use was in refractories (10 tons). Other nonenergy uses included hardeners in

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magnesium-thorium alloys (6 tons), mantles for Welbasch incandescent lamps (6 tons), thoriated tungsten welding rods (3 tons), and electronic and chemical applications and research (9 tons). In 1979, nonenergy uses consumed about 32 tons of ThO_2. The chief use was in refractories (9 tons). Other nonenergy uses were as follows: mantles (6 tons), magnesium-thorium alloy (6 tons), welding rods (4 tons), electronic and chemical applications and other applications and research (7 tons).

DOE had a research and development program to develop and demonstrate its light-water cooled and moderated nuclear reactor using the thorium/uranium-233 fuel system. This program involved development and operation of an LWBR in the Shippingport, Pa., atomic power station. The LWBR continued producing electrical power for the Duquesne Light Co. power distribution grid during 1978 and 1979.

As of October 1979, the core had exceeded its minimum guaranteed power rating and energy output. The LWBR was expected to operate for at least 2 to 3 years beyond the end of 1979. Initial loading of about 46 tons of thorium took place in 1977. At the end of its life, the spent core will be removed from Shippingport and sent to DOE's National Engineering Laboratory in Idaho for detailed examination and determination of breeding performance.

The Fort St. Vrain HTGR completed its first refueling on May 16, 1979, when a reload section containing about 3 tons of thorium was added. The core of the reactor contained about 22 tons of thorium. The commercial reactor was the Nation's first to use a prestressed concrete reactor vessel, helium coolant, steam turbine-drive, primary coolant helium circulators, and a fully ceramic core utilizing the uranium-thorium fuel cycle. The reactor continued to run at 70% of its electrical power capacity in 1978 and 1979, and pending the results of tests, was scheduled to reach full operating capacity on July 4, 1980.

STOCKS

On December 31, 1978, the stockpile inventory of the General Services Administration (GSA) totaled 7,146,327 pounds of thorium nitrate (1,604 short tons ThO_2 equivalent). The thorium nitrate stockpile goal remained at 1.8 million pounds (418 short tons ThO_2 equivalent). The DOE inventory as of December 31, 1978, was 851 short tons of thorium contained in various compounds.

The GSA stockpile inventory on December 31, 1979, totaled 7,205,337 pounds of thorium nitrate (1,617 short tons ThO_2 equivalent). The thorium nitrate stockpile goal remained at 1.8 million pounds. The DOE inventory as of December 31, 1979, was 1,206 short tons of thorium contained in various compounds. In 1979 DOE was given 355 tons of thorium by a domestic company.

PRICES

The average declared value of imported monazite (mostly from Australia and Malaysia) was $208 per short ton in 1978 and $240 per short ton in 1979. The average price per short ton of Australian monazite quoted in Metal Bulletin (London) was A$223 to A$268 (US$206 to US$248) at the end of 1978 and was A$313 to A$357 (US$282 to US$322) by the end of 1979.

Prices for thorium compounds varied depending upon purity and quality. Thorium oxide, 99.99% pure, was quoted at $11.23 per pound in 1978 and $11.79 per pound in 1979. Nuclear-grade thorium oxide powder was quoted at $16.30 per pound in 1979, and thorium metal in pellets remained at $15.00 per pound during 1978 and 1979.

FOREIGN TRADE

During 1978, the United States exported thorium ores and concentrates for the first time since 1974. No thorium ores or concentrates were exported during 1979. Other thorium export data were combined with those of uranium. Although these two elements are not statistically differentiated, it was believed that the amount of thorium exported is minor.

Imports of monazite in 1978 mainly for rare-earth content increased over those of 1977. Monazite imports in 1979 fell below those of 1978.

Table 2.—U.S. foreign trade in thorium and thorium-bearing materials

	1977		1978		Principal sources and destinations, 1978	1979		Principal sources and destinations, 1979
	Quantity (pounds)	Value	Quantity (pounds)	Value		Quantity (pounds)	Value	
EXPORTS								
Ore and concentrate[1]	--	--	1,091,220	$87,500	All to France.	--	--	--
Metals and alloys[2]	2,840	$137,199	5,434	76,524	Japan 3,991;France 368; Brazil 346; Others 729.	10,651	$216,630	Sweden 6,828; Canada 2,206; United Kingdom 868; Others 750.
Compounds[2]	245,570	2,847,944	330,476	14,280,723	United Kingdom 327,968; Federal Republic of Germany 655; Sweden 467; Others 1,386.	37,367	430,472	Chile 20,000; Philippines 6,041; France 5,615; Others 5,711.
IMPORTS								
Ore and concentrate:								
Monazite (short tons)	5,480	900,191	7,711	1,602,320	Australia 5,532; Malaysia 1,276; Thailand 846; Nigeria 58.	6,931	1,676,939	Australia 6,269; Malaysia 618; Thailand 41; South Africa 3.
ThO_2 content	657,600	XX	925,320	XX		831,720	XX	
Waste and scrap	--	--	--	--	--	1,006	18,209	--
Compounds:								
Nitrate	46,400	118,555	47,567	147,044	France 45,805; Netherlands 1,102; Canada 660.	47,415	162,837	France 31,431; Canada 15,984.
Oxide	10,911	46,147	40,406	239,956	France 39,461; Netherlands 846; Canada 99.	31,509	160,490	France 22,509; Netherlands 6,808; Others 2,192.
Oxide equivalent, in gas mantles[e] [3]	1,288	191,165	1,215	206,754	Malta 588; Hong Kong 186; Brazil 182; Others 259.	2,867	476,842	Malta 1,851; Austria 319; Brazil 318; Others 379.
Other	478	52,947	953	102,138	Switzerland 941; United Kingdom 11; Federal Republic of Germany 1.	181	33,688	Switzerland 156; United Kingdom 22; Federal Republic of Germany 3.

[e] Estimate. XX Not applicable.

[1] No thorium ore and concentrates were exported in 1977 and 1979.

[2] Includes uranium; thorium and uranium are undifferentiated in official statistics.

[3] Based on the manufacture of 1,000 gas mantles per pound ThO_2.

WORLD REVIEW

The predominate source of the world's thorium is monazite, a byproduct of titanium and tin mining. Australia, India, Malaysia, Brazil, and the United States continued to be the leading monazite producers among market economy countries. Of those countries, Australia and Malaysia were the only significant sources of monazite without government export restrictions. Both countries had little or no domestic processing facilities beyond the monazite concentrating stage at the mine. Because of this, all the monazite produced was exported mainly to the United States, France, the United Kingdom, and India.[6] Production quantities do not reflect world demand for thorium since monazite is processed mainly for its rare-earth element content.

An agreement for cooperation in the use of thorium reactors between the Federal Republic of Germany and Brazil was expected to result from a trip to the Federal Republic of Germany in March 1978 by Brazilian President Ernesto Geisel. Brazil's thorium reserves are large (1.3 million short tons) compared with uranium reserves (74,000 short tons of U_3O_8). Brazilian participation in thorium reactors would be postponed until operating results are obtained from the first German high-temperature reactor, a 300-Mwe (megawatt electrical) pilot plant under construction and due to start up in 1981.[7]

Table 3.—Monazite concentrate: World production, by country

(Short tons)

Country[1]	1976	1977	1978[p]	1979[e]
Australia	[r]5,853	9,377	14,864	17,000
Brazil	1,775	2,691	[e]2,700	2,700
India[e]	3,300	3,014	3,607	3,100
Korea, Republic of[e]	10	10	10	10
Malaysia[r]	2,071	2,179	1,392	2,200
Nigeria[e]	20	20	20	--
Sri Lanka	1	[e]5	220	220
Thailand	--	--	845	800
United States	W	W	W	W
Zaire	265	106	85	85
Total	[r]13,295	17,402	23,743	26,115

[e]Estimate. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.

[1]Indonesia and North Korea may produce monazite, but information for estimating output is inadequate.

Australia.—Dillingham Corp., a Honolulu-based company, has decided to stop all mineral sands mining in Australia due to the Federal Government's decision to ban all beach sand mining on Fraser Island, Queensland. Another factor in Dillingham's decision was the announcement by the New South Wales government that future mining in areas designated as national parks be banned. The company has claimed compensation of A$23 million versus the government's offer of A$4 million, stating that the Fraser Island decision has reduced its reserves from a life of 20 years to 5 years.[8]

Canada.—The Atomic Energy of Canada Research Co., part of Atomic Energy of Canada Ltd., was conducting a study in 1978-79 to determine the best possible way to use thorium in its CANDU reactor system. Its research has been concentrated in five areas: Physics, separation techniques, fuel irradiation, fuel fabrication, and safeguard techniques.

India.—The Bhabha Atomic Research Center (BARC) proposed a new scheme for utilization of India's thorium reserves, which would result in a faster growth of nuclear power by avoiding the intermediate step of fast breeders. Under the new scheme, thorium would be converted into fissionable U_{233} by means of an accelerator (atom smasher). The U_{233} thus produced would be used along with thorium, a fuel used in reactors of the same type now working in Rajasthan.

The first phase of India Rare Earth Limited's Orissa Mineral Sands Complex (OMSC) near Chatrapur is likely to be onstream in 1981. In the first phase, OMSC should produce 4,400 tons of monazite annually.[9]

Kerala Minerals & Metals Ltd. was setting up a beach sands processing complex at Quilon, Kerala. The complex will consist of a deep dredging operation and a beneficiation and mineral separation plant that should produce 3,300 tons of monazite annually.[10]

Beach sands containing 3-5% monazite have been discovered along the Visakhapatnam coast. The deposit was reported to be 3 miles long, 20 feet wide, and about 5 feet deep.[11]

India estimated its monazite reserves in beach sands and inland placer deposits at 4.4 million short tons.[12]

Malaysia.—The Kinta Kellas Tin Dredging Co. produced monazite in 1979 after the development of a new openpit mine.[13]

South Africa, Republic of.—Three short tons of monazite concentrate was shipped from the Van Rhynsdorp district to a company in the United States and a company in France for evaluation. Test results indicated that the monazite concentrate was not suitable for treatment by existing processes.

Thailand.—In early 1978, it was reported that the ban on the export of monazite would be eased.[14] The United States imported 846 tons of monazite from Thailand in 1978 and 41 tons in 1979.

TECHNOLOGY

An occupational health study for DOE and the Nuclear Regulatory Commission (NRC) to determine possible effects of thorium on the human body continued at the Argonne National Laboratory, Argonne, Ill. The study involves former employees of the now-closed Lindsay Light and Chemical Co., a former thorium processor. A preliminary report has been published.[15]

The Lovelace Inhalation Toxicology Research Insititute began a study in 1978 to develop physical and mathematical models for the release of radon and other U_{233} daughter products from irradiated uranium oxide and thorium oxide fuels. These studies were scheduled to be completed in 1980. The institute planned to initiate studies that would involve the inhalation of uranium oxide and thorium oxide aerosols by laboratory animals.

Research by General Atomic Co. (GA) on the use of a thorium breeder blanket in a gas-cooled fast-breeder reactor (GCFR) continued in 1978 and 1979. Reportedly, $15 million in 1978 and $26 million in 1979 was spent on GCFR research.

The results of preliminary studies of a laser-driven fusion-fission hybrid concept utilizing the Th_{232}-U_{233} breeding cycle were reported.[16]

It was reported that use of the thorium fuel cycle improves uranium fuel utilization in all thermal reactors because of the favorable physics characteristics of the U_{233} that is bred during operation.[17]

A method utilizing solvent extraction coupled with liquid scintillation spectrometry has been developed for the assay of uranium and thorium in fertilizers and phosphate-containing minerals and chemicals.[18]

It was reported that some thorium fuels have distinct advantages compared with those employing recycled neutron plutonium in terms of both reduced neutron dose rates and long-term alpha decay heating.[19]

A paper stated that the attractive properties of thorium-derived fuel and the existence of large deposits of thorium-bearing sands, particularly in locations where uranium is scarce, provided incentives for thorium utilization.[20]

A paper compared three axial fuel management strategies for use in a CANDU-PHW reactor operating on a self-sufficient, equilibrium thorium cycle.[21]

A report was published that presented an overview of the current U.S. capability for large-scale production of reactor-grade ThO from domestic sources.[22]

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Tin

By James F. Carlin, Jr.[1] and Keith L. Harris[1]

World tin production increased significantly in 1978 and 1979 in response to successive years of record high tin prices. The 1978 average Metals Week composite price of Straits (Malaysian) tin was 629.58 cents per pound, and increased in 1979 to a new record high of 753.89 cents per pound. These factors resulted in a slight deficit of supply to demand in 1978, and an approximate balance of supply and demand in 1979 following many years of a net supply deficit situation.

Legislation and Government Programs.—On September 14, 1978 the General Services Administration (GSA) concluded sales of tin authorized for disposal from the U.S. Government stockpile excess; only 330 tons was sold in 1978 while shipments totaled 345 tons. Although the stockpile contained 203,691 tons at yearend 1979 and the goal was 33,021 tons, none of the numerous bills introduced in Congress to authorize additional tin disposals was enacted. Also, the bill authorizing the U.S. contribution of up to 5,000 long tons of tin to the ITC buffer stock was not enacted by yearend 1979. The United States continued as a member of the Fifth International Tin Agreement (ITA), the only metal commodity agreement in which the United States has participated.

The depletion allowances for tin remained 22% for domestic deposits and 14% for foreign deposits.

Table 1.—Salient tin statistics

(Metric tons)

	1975	1976	1977	1978	1979
United States:					
Production:					
Mine	W	W	W	W	W
Smelter	6,500	5,700	6,700	5,900	4,600
Secondary	15,869	16,446	18,503	21,100	21,493
Exports (including reexports)	3,596	2,338	5,480	4,692	3,417
Imports for consumption:					
Metal	44,366	45,055	47,774	46,776	48,355
Ore (tin content)	6,415	5,733	6,724	3,873	4,529
Consumption:					
Primary	43,620	51,767	47,596	48,403	49,496
Secondary	12,180	11,161	13,136	13,128	12,969
U.S. industry yearend stocks	25,684	21,485	21,366	17,217	8,126
Prices, average cents per pound:					
New York market	339.82	349.24	499.38	587.03	711.45
New York composite	NA	379.82	534.60	629.58	753.89
London	311.41	347.42	486.92	583.83	700.93
Penang	303.55	338.94	485.96	567.65	672.33
World production:					
Mine	222,288	[r]228,364	235,909	[p]251,183	[e]256,002
Smelter	227,895	[r]233,622	232,378	[p]246,972	[e]259,189

[e]Estimate. [p]Preliminary. [r]Revised. NA Not available. W Withheld to avoid disclosing company proprietary data.

DOMESTIC PRODUCTION

PRIMARY TIN

Mine Production.—Domestic production of tin in 1978 and 1979 was less than 200 tons annually. Some of the output came from Colorado as a byproduct of molybdenum mining. Some tin concentrate was produced at a placer operation in New Mexico and in conjunction with exploration and development in Alaska.

In 1979, Texasgulf Corp. and Associated Metals and Minerals Corp. entered into a joint-venture agreement with Lost River Mining Corp. Ltd. to explore further the Lost River tin-tungsten-fluorite deposit on Seward Peninsula in Alaska. After several months of exploration, the joint venture was terminated.

Smelter Production.—Gulf Chemical & Metallurgical Corp. (GCMC) imported tin-in-concentrate, mostly from Bolivia, which formed the base feed together with domestic tin concentrate and secondary tin-bearing materials. Total tin production was estimated at 5,900 tons in 1978 and 4,600 tons in 1979.

GCMC commenced production in 1979 with its new, $10 million Kaldo furnace. The new furnace, which replaced the existing reverberatory furnaces, decreased operating costs and enabled GCMC to process low-grade tin-bearing materials, including its own stockpile of tin residues and slags. GCMC expected future production to be 4,000 tons per year with about 80% of production derived from low-grade secondary sources.

SECONDARY TIN

The United States is the world's largest producer of secondary tin. In both 1978 and 1979, secondary tin production continued the pattern of steady increases of recent years.

Proler International Corp. began operations in 1978 at its new continuous-process detinning plant located at Randolph, Ariz. The plant has an annual capacity of about 90 tons of electrolytic tin and a throughput of 5,500 tons of tinplate scrap per month. This is Proler's second plant of this type, complementing the older facility in Benton, Tex.

Table 2.—Secondary tin recovered from scrap processed at detinning plants in the United States

	1978	1979
Tinplate scrap treated__________metric tons__	714,850	841,430
Tin recovered in the form of:		
Metal__________do__	1,324	1,536
Compounds (tin content)__________do__	463	433
Total[1]__________do__	1,787	1,969
Weight of tin compounds produced__________do__	1,803	1,256
Average quantity of tin recovered per metric ton of tinplate scrap used__________kilograms__	2.50	2.34
Average delivered cost of tinplate scrap__________per metric ton__	$66.04	$90.73

[1] Recovery from tinplate scrap treated only. In addition, detinners recovered 213 metric tons (215 metric tons in 1978) of tin as metal and in compounds from tin-base scrap and residues in 1979.

Table 3.—Tin recovered from scrap processed in the United States, by form of recovery

(Metric tons)

Form of recovery	1978	1979
Tin metal:		
At detinning plants	1,539	1,749
At other plants	26	18
Total	1,565	1,767
Bronze and brass:		
From copper-base scrap	12,357	12,044
From lead- and tin-base scrap	62	46
Total	12,419	12,090
Solder	4,363	5,282
Type metal	1,038	584
Babbitt	521	441
Antimonial lead	712	867
Chemical compounds	463	433
Miscellaneous[1]	19	29
Total	7,116	7,636
Grand total	21,100	21,493
Value (thousands)	$273,072	$336,900

[1] Includes foil and terne metal.

Table 4.—Stocks, receipts, and consumption of new and old scrap and tin recovered in the United States

(Metric tons)

Type of scrap and class of consumer	Gross weight of scrap						Tin recovered		
	Stocks Jan. 1	Receipts	Consumption			Stocks Dec. 31			
			New	Old	Total		New	Old	Total
1978									
Copper-base scrap:									
Secondary smelters:									
Auto radiators (unsweated)	4,180	73,368	--	73,444	73,444	4,104	--	3,158	3,158
Brass, composition or red	4,331	62,048	14,027	48,953	62,980	3,399	538	1,813	2,351
Brass, low (silicon bronze)	530	2,842	1,088	1,951	3,039	333	--	16	16
Brass, yellow	7,223	41,450	5,540	38,506	44,046	4,627	14	434	448
Bronze	1,872	17,150	2,851	14,537	17,388	1,634	224	1,139	1,363
Low-grade scrap and residues	16,355	121,569	100,977	25,489	126,466	11,458	18	--	18
Nickel silver	759	2,339	345	2,313	2,658	440	3	19	22
Railroad-car boxes	231	2,366	--	2,455	2,455	142	--	117	117
Total	35,481	323,132	124,828	207,648	332,476	26,137	797	6,696	7,49
Brass mills:[1]									
Brass, low (silicon bronze)	3,516	48,288	48,288	--	48,288	3,037	--	--	--
Brass, yellow	24,743	277,189	277,189	--	277,189	21,963	187	--	187
Bronze	722	5,234	5,234	--	5,234	598	251	--	251
Nickel silver	2,406	16,119	16,119	--	16,119	2,769	--	--	--
Total	31,387	346,830	346,830	--	346,830	28,367	438	--	438
Foundries and other plants:[2]									
Auto radiators (unsweated)	1,119	9,666	--	10,009	10,009	776	--	451	451
Brass, composition or red	333	11,383	1,937	9,336	11,273	443	91	443	534
Brass, low (silicon bronze)	86	1,707	1,641	89	1,730	63	--	--	--
Brass, yellow	456	11,557	7,472	4,072	11,544	469	12	47	59
Bronze	913	696	259	417	676	933	19	31	50
Low-grade scrap and residues	8	8	--	4	4	12	--	--	--
Nickel silver	10	113	110	6	116	7	--	--	--
Railroad-car boxes	803	7,414	--	7,342	7,342	875	--	348	348
Total	3,728	42,544	11,419	31,725	42,694	3,578	122	1,320	1,442
Total tin from copper-base scrap	XX	XX	XX	XX	XX	XX	1,357	8,016	9,373
Lead-base scrap:									
Smelters, refiners, and others:									
Babbitt	299	5,339	--	5,214	5,214	424	--	468	468
Battery lead plates	58,321	711,687	--	710,350	710,350	59,658	--	981	981
Drosses and residues	32,367	172,690	174,187	--	174,187	30,870	3,366	--	3,366
Solder and tinny lead	273	13,909	--	13,845	13,845	337	--	2,417	2,417
Type metal	2,783	25,986	--	25,769	25,769	3,000	--	1,224	1,224
Total	94,043	929,611	174,187	755,178	929,365	94,289	3,366	5,090	8,456
Tin-base scrap:									
Smelters, refiners, and others:									
Babbitt	23	201	--	199	199	25	--	166	166
Block-tin pipe	8	160	--	160	160	8	--	158	158
Drosses and residues	190	1,752	1,812	--	1,812	130	922	--	922
Pewter	--	26	--	25	25	1	--	22	22
Total	221	2,139	1,812	384	2,196	164	923	346	1,2
Tinplate and other scrap:									
Detinning plants	--	--	714,850	--	714,850	--	2,002	--	2,002
Grand total	XX	XX	XX	XX	XX	XX	7,648	13,452	21,10

See footnotes at end of table.

Table 4.—Stocks, receipts, and consumption of new and old scrap and tin recovered in the United States —Continued

(Metric tons)

Type of scrap and class of consumer	Gross weight of scrap						Tin recovered		
	Stocks Jan. 1	Receipts	Consumption			Stocks Dec. 31			
			New	Old	Total		New	Old	Total
1979									
Copper-base scrap:									
Secondary smelters:									
Auto radiators (unsweated)	4,104	84,474	--	84,976	84,976	3,602	--	3,654	3,654
Brass, composition or red	3,399	66,727	13,128	54,804	67,932	2,194	501	2,022	2,523
Brass, low (silicon bronze)	333	3,489	1,264	2,063	3,327	445	--	15	15
Brass, yellow	4,627	46,178	5,789	41,248	47,037	3,768	15	439	454
Bronze	1,684	18,255	3,304	14,998	18,302	1,587	261	1,176	1,437
Low-grade scrap and residues	11,458	278,370	203,857	73,783	277,640	12,188	21	--	21
Nickel silver	440	3,629	500	2,964	3,464	605	5	25	30
Railroad-car boxes	142	1,822	--	1,770	1,770	194	--	84	84
Total	26,137	502,894	227,842	276,606	504,448	24,583	803	7,415	8,218
Brass mills:[1]									
Brass, low (silicon bronze)	2,037	50,698	50,698	--	50,698	3,012	--	--	--
Brass, yellow	21,963	295,843	295,843	--	295,843	21,600	211	--	211
Bronze	598	5,418	5,418	--	5,418	480	260	--	260
Nickel silver	2,769	24,857	24,857	--	24,857	3,670	--	--	--
Total	28,367	376,811	376,811	--	376,811	28,762	471	--	471
Foundries and other plants:[2]									
Auto radiators (unsweated)	776	9,057	--	9,147	9,147	686	--	411	411
Brass, composition or red	443	12,826	3,647	8,925	12,572	697	173	424	597
Brass, low (silicon bronze)	63	347	229	128	357	53	--	2	2
Brass, yellow	469	11,099	6,426	4,709	11,135	433	13	60	73
Bronze	933	821	518	336	854	900	38	26	64
Low-grade scrap and residues	12	7	--	19	19	--	--	--	--
Nickel silver	7	131	11	117	128	10	--	--	--
Railroad-car boxes	875	6,985	--	7,153	7,153	707	--	340	340
Total	3,578	41,273	10,831	30,534	41,365	3,486	224	1,263	1,487
Total tin from copper-base scrap	XX	XX	XX	XX	XX	XX	1,498	8,678	10,176
Lead-base scrap:									
Smelters, refiners, and others:									
Babbitt	424	5,964	--	6,134	6,134	254	--	518	518
Battery lead plates	59,658	732,398	--	749,675	749,675	42,381	--	1,034	1,034
Drosses and residues	30,870	172,311	183,036	--	183,036	20,145	4,009	--	4,009
Solder and tinny lead	337	14,365	--	13,387	13,387	1,315	--	2,078	2,078
Type metal	3,000	16,315	--	16,787	16,787	2,528	--	877	877
Total	94,289	941,353	183,036	785,983	969,019	66,623	4,009	4,507	8,516
Tin-base scrap:									
Smelters, refiners, and others:									
Babbitt	25	140	--	152	152	13	--	128	128
Block-tin pipe	8	112	--	111	111	9	--	110	110
Drosses and residues	130	832	935	--	935	27	375	--	375
Pewter	1	6	--	7	7	--	--	6	6
Total	164	1,090	935	270	1,205	49	375	244	619
Tinplate and other scrap:									
Detinning plants	--	--	841,430	--	841,430	--	2,182	--	2,182
Grand total	XX	XX	XX	XX	XX	XX	8,064	13,429	21,493

XX Not applicable.

[1] Brass-mill stocks include home scrap, and purchased-scrap consumption is assumed equal to receipts; therefore, lines and total in brass-mill section do not balance.

[2] Omits "machine-shop scrap."

CONSUMPTION AND USES

Tin consumption in 1978 and 1979 registered slight increases over 1977 levels. While primary tin usage increased slightly each year, secondary tin consumption declined slightly each successive year. In 1978 and 1979, solder became the major end use sector for tin, displacing tinplate for the first time since 1973. A 5% decrease in tinplate production in 1978 and the continued declining ratio of tin on tinplate contributed to the displacement. The decline in tinplate production was attributed to the beverage can manufacturers' conversion from three-piece soldered-side-seam cans to two-piece drawn and wall-ironed cans; the two-piece cans require about one-quarter less steel to fabricate.

The operations of Jones & Laughlin Steel Corp. and Youngstown Sheet & Tube Co. were merged after LTV Corp., the parent company of Jones & Laughlin, took over Youngstown's parent firm, Lykes Corp. Jones & Laughlin, which operated three electrolytic tinplate lines (ETL) at its Aliquippa works, assumed control of the two ETLs and one tin-free steel line at Youngstown's Indiana Harbor works. With a combined annual capacity of 850,000 tons, LTV Corp. ranked fourth in tinplate capacity, following United States Steel Corp., National Steel Corp., and Bethlehem Steel Corp.

In 1978, brass mills consumed 769 tons of primary tin and 407 tons of secondary tin compared with the 1977 levels of 715 tons and 356 tons, respectively. In 1979, brass mill usage increased further to 801 tons of primary tin and 525 tons of secondary tin.

Table 5.—Consumption of primary and secondary tin in the United States

(Metric tons)

	1975	1976	1977	1978	1979
Stocks Jan. 1[1]	21,051	19,510	16,894	16,858	13,584
Net receipts during year:					
Primary	42,430	49,995	48,215	46,821	44,914
Secondary	2,699	2,019	4,025	2,541	2,636
Scrap	10,568	10,189	10,604	10,499	7,430
Total receipts	55,697	62,203	62,844	59,861	54,980
Total available	76,748	81,713	79,738	76,719	68,564
Tin consumed in manufactured products:					
Primary	43,620	51,767	47,596	48,403	49,496
Secondary	12,180	11,161	13,136	13,128	12,969
Total	55,800	62,928	60,732	61,531	62,465
Intercompany transactions in scrap	1,438	1,891	2,148	1,604	1,602
Total processed	57,238	64,819	62,880	63,135	64,067
Stocks Dec. 31 (total available less total processed)	19,510	16,894	16,858	13,584	4,497

[1] Includes tin in transit in the United States.

Table 6.—Tin content of tinplate produced in the United States

(Metric tons)

Year	Tinplate waste-waste, strips, cobbles, etc., gross weight	Tinplate (all forms)		
		Gross weight	Tin content[1]	Tin per metric ton of plate (kilograms)
1975	336,967	4,018,295	18,869	4.7
1976	439,988	4,372,639	20,766	4.7
1977	355,841	4,228,325	18,539	4.4
1978	338,351	4,022,524	17,280	4.3
1979	360,852	4,236,578	17,929	4.2

[1] Includes small tonnage of secondary tin and tin acquired in chemicals.

Table 7.—Consumption of tin in the United States, by finished product

(Metric tons of contained tin)

Product	1978			1979		
	Primary	Secondary	Total	Primary	Secondary	Total
Alloys (miscellaneous)	2,195	159	2,354	2,248	180	2,428
Babbitt	1,835	511	2,346	1,830	413	2,243
Bar tin	424	W	424	567	W	567
Bronze and brass	3,012	6,036	9,048	2,709	5,981	8,690
Chemicals	4,557	W	4,557	4,797	W	4,797
Collapsible tubes and foil	673	W	673	686	W	686
Solder	12,952	4,818	17,770	13,249	4,773	18,022
Terne metal	(1)	(1)	(1)	(1)	(1)	(1)
Tinning	2,349	82	2,431	2,498	86	2,584
Tinplate[2]	17,280	--	17,280	17,929	--	17,929
Tin powder	1,360	--	1,360	1,435	W	1,435
Type metal	41	130	171	26	114	140
White metal[3]	1,484	W	1,484	1,258	W	1,258
Other	241	1,392	1,633	264	1,422	1,686
Total	48,403	13,128	61,531	49,496	12,969	62,465

W Withheld to avoid disclosing company proprietary data; included in "Other."

[1] Included in "Alloys (miscellaneous)."

[2] Includes secondary pig tin and tin acquired in chemicals.

[3] Includes pewter, britannia metal, and jewelers' metal.

STOCKS

Plant stocks of pig tin were 4,823 tons at yearend 1978, a 29% decline from 1977 levels and at yearend 1979 stood at 3,671 tons, less than a month's supply. As the price of tin increased throughout the 1978-79 period, consumers drew down their inventories and tried to time tin purchases with brief dips in the market price.

Table 8.—U.S. industry yearend tin stocks

(Metric tons)

	1975	1976	1977	1978	1979
Plant raw materials:					
Pig tin:					
Virgin[1]	7,160	6,647	6,173	4,129	3,480
Secondary	317	243	645	694	191
In process[2]	12,033	10,004	10,040	8,761	826
Total	19,510	16,894	16,858	13,584	4,497
Additional pig tin:					
Jobbers-importers	2,059	1,009	1,436	275	258
Afloat to United States	4,115	3,582	3,072	3,358	3,371
Total	6,174	4,591	4,508	3,633	3,629
Grand total	25,684	21,485	21,366	17,217	8,126

[1] Includes tin in transit in the United States. In 1979, the figure represents scrap purchased only.

[2] Tin content, including scrap.

PRICES

The price of tin in the 1978-79 period fluctuated considerably about a generally rising trend. Prices were influenced by the uncertainty of passage of U.S. tin stockpile disposal legislation, the declining value of the U.S. dollar, mine and smelter work disruptions, the lack of GSA sales and ITC buffer stock tin availability, the ITC price range hikes, and the change in marketing policy by the Malaysian Mining Corp. Bhd. (MMC).

The average 1978 composite price of tin at New York increased about $1 over the 1977 level to $6.30 per pound, and the average 1979 composite price advanced over $1 to $7.54 per pound.

Starting on August 1, 1978, the MMC, 71% owned by the Malaysian Government and 29% owned by Charter Consolidated Ltd., revised its marketing procedures. MMC began marketing its toll-smelted tin production exclusively through the Anglo Chemical & Ore Co., a London company associated with Charter Consolidated, and a subsidiary of Philipp Brothers, Division of Engelhard Minerals & Chemicals Corp. Formerly, MMC sold its concentrates to the Malaysian smelters and the resultant metal was sold on the Penang market. After the change, Penang sales declined from a daily average of 239 tons from January 1 through July 31, to 201 tons from August 1 through December 31, 1978.

Table 9.—Monthly composite price of Straits tin for delivery in New York

(Cents per pound)

Month	1978			1979		
	High	Low	Average	High	Low	Average
January	613.77	572.58	592.30	701.00	668.31	684.23
February	604.44	575.15	598.36	737.24	700.00	720.06
March	590.24	534.01	557.57	754.46	727.36	741.80
April	553.80	526.63	539.62	752.54	726.72	735.91
May	585.01	547.97	570.27	751.35	727.73	740.77
June	611.26	577.73	600.92	768.48	744.11	753.92
July	616.01	598.53	607.00	773.07	727.01	759.52
August	660.65	616.86	639.25	753.35	732.42	739.52
September	687.15	654.98	674.84	784.61	747.45	761.95
October	805.79	674.12	739.18	792.72	772.99	781.40
November	790.17	704.37	745.02	824.95	783.13	799.63
December	729.72	680.08	695.62	842.02	809.79	827.95
Average	XX	XX	629.58	XX	XX	753.89

XX Not applicable.
Source: Metals Week.

FOREIGN TRADE

Exports of tin metal declined successively in 1978 and 1979. Reexports continued to be larger than exports, as has been the case since 1975. Imports of tin-in-concentrates in both 1978 and 1979 were substantially below levels of recent years. Bolivia, the largest source of tin concentrates, has been increasing its own smelter capacity, thus decreasing the availability of concentrates on the world market.

The tariff on tin in all forms—ore and concentrate, metal, and waste and scrap—remained free.

Table 10.—U.S. exports and imports for consumption of tin, tinplate, and terneplate in various forms

Year	Ingots, pigs, and bars				Tinplate and terneplate				Tinplate circles, strips, and cobbles		Tinplate scrap	
	Exports		Reexports		Exports		Imports		Exports		Imports	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1977	545	$5,176	4,925	$50,175	296,614	$115,579	4,046	$1,372	21,347	$2,821	11,335	$778
1978	498	5,926	4,194	51,901	339,529	142,389	3,836	1,479	(1)	(1)	5,234	749
1979	568	8,074	2,849	42,783	399,525	204,986	2,942	1,292	(1)	(1)	5,471	513

[1] Included with exports of tinplate and terneplate.

Table 11.—U.S. imports for consumption and exports of miscellaneous tin, tin manufactures, and tin compounds

Year	Miscellaneous tin and manufactures				Tin compounds	
	Imports			Exports	Imports	
	Tinfoil, tin powder, flitters, metallics, tin and manufactures, n.s.p.f.	Dross, skimmings, scrap, residues, and tin alloys, n.s.p.f.		Tin scrap and other tin-bearing material, except tinplate scrap	Quantity (metric tons)	Value (thousands)
	Value (thousands)	Quantity (metric tons)	Value (thousands)	Value (thousands)		
1977	$3,733	813	$1,816	$9,328	170	$1,448
1978	32,276	709	5,365	11,232	240	2,472
1979	16,732	1,350	11,011	12,513	202	2,473

Table 12.—U.S. imports for consumption of tin, by country

Country	1978		1979	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Concentrates (tin content):				
Bolivia	3,541	$40,089	3,745	$48,493
Canada	--	--	583	2,968
Indonesia	165	1,616	--	--
Peru	82	943	169	2,218
Singapore	85	863	--	--
South Africa, Republic of	--	--	32	339
Total	3,873	43,511	4,529	54,018
Metal:[1]				
Australia	20	220	135	2,030
Belgium-Luxembourg	155	2,092	100	1,582
Bolivia	5,768	69,258	5,387	77,595
Brazil	1,810	22,123	933	13,423
Canada	3	55	58	116
Chile	--	--	276	3,865
China:				
Mainland	1,571	15,494	185	2,686
Taiwan	50	595	--	--
Germany, Federal Republic of	148	1,856	25	405
Hong Kong	--	--	1	17
India	--	--	40	591
Indonesia	5,664	70,609	5,429	78,917
Korea, Republic of	5	62	--	--
Macao	--	--	20	300
Malaysia	23,928	291,189	23,448	343,814
Mexico	1	17	5	89
Netherlands	50	604	--	--
Peru	20	239	--	--
Philippines	20	306	--	--
Singapore	230	2,914	1,070	16,451
South Africa, Republic of	--	--	253	883
Thailand	6,865	85,698	10,440	148,803
United Kingdom	468	5,274	550	8,533
Total	46,776	568,600	48,355	700,050

[1] Bars, blocks, pigs, or granulated.

WORLD REVIEW

International Tin Agreement.—Countries who were signatory to the Fifth International Tin Agreement (ITA) continued to discuss the differences between producer and consumer viewpoints such as the appropriate floor and ceiling price ranges for the tin buffer stock. The producers believed the floor and ceiling price ranges should be related to current tin market price and consumers maintained that the ranges should be based on production costs. During 1978-79, the International Tin Council revised upwards the buffer stock price range on two occasions as shown in table 13. The U.S. Government was committed to contribute up to 5,000 long tons of tin to the ITC buffer stock; several bills to provide for this along with the sale of various amounts of tin from the stockpile were introduced in 1978-79 but none was enacted into law.

Table 13.—Changes in ITC buffer stock range

	Previous range		Effective 7/14/78		Effective 7/20/79	
	M$ per picul	U.S. equivalent dollars per pound	M$ per picul	U.S. equivalent dollars per pound	M$ per picul	U.S. equivalent dollars per pound
Floor price	1,200	3.66	1,350	4.40	1,500	5.25
Lower sector	1,200-1,300	3.66-3.96	1,350-1,450	4.40-4.72	1,500-1,650	5.25-5.77
Middle sector	1,300-1,400	3.96-4.27	1,450-1,600	4.72-5.21	1,650-1,800	5.77-6.30
Upper sector	1,400-1,500	4.27-4.57	1,600-1,700	5.21-5.54	1,800-1,950	6.30-6.82
Ceiling price	1,500	4.57	1,700	5.54	1,950	6.82

Australia.—Production was again dominated by the operations of Renison Ltd., 51% owned by Consolidated Gold Fields Australia Ltd., accounting for more than half of total Australian production in both 1978 and 1979. Reserves at the world's largest underground tin mine, located at Renison Bell in Tasmania, were increased 14% to 13.7 million tons of ore, but the average grade decreased slightly to 1.14% tin with the discovery of 2.2 million tons of ore averaging 1.06% tin. Renison will commit $18 million to increase ore throughput of its concentrator from 630,000 to 850,000 tons per year. The expansion, scheduled for completion by late 1980, will include increased mining and service facilities and additional housing and associated infrastructure in Zeehan to accomodate 80 more employees on the work force.

In 1978, Abminco N.L., operator of the Ardlethan, Aberfoyle, and Cleveland mines, became a wholly owned subsidiary of Aberfoyle Ltd. As a result, Aberfoyle became Australia's second largest tin producer, Australian Pty. Ltd.'s interest declined from 55% to 45%, and Cominco Exploration Pty. Ltd. became wholly owned by Aberfoyle.

Eastmet Ltd. encountered tin at its Doradilla prospect near Bourke in New South Wales. The prospect was encouraging enough that Aberfoyle Ltd. decided to proceed with exploration work which will allow it to gain a 51% interest in the prospect.

Metals Exploration Ltd. reached an agreement with Comstaff Pty. Ltd. and Preussag Australia Pty. Ltd. to explore the abandoned Mt. Bischoff tin mine in Tasmania. Between 1871 and 1947, this mine produced 56,000 tons of tin metal.

Southland Mining Ltd. sold its Tableland Tin Dredging operations to Oakbridge Ltd. The dredging operations are located at Mount Garnet and have an annual capacity of 4 million cubic yards. Oakbridge already operated the Ravenshoe dredge and sluicing plants nearby.

A consortium headed by Newmont Mining Corp. announced a sizable new tin deposit in the Glen Innes district of New South Wales. Drilling results indicated 19 million tons of mineralization grading 0.17% tin, along with copper and silver, minable by open pit methods.

Associated Tin Smelter's plant near Sydney remained the country's only smelter; it toll-smelted for the various tin mines, with production of about 5,500 tons yearly. Greenbushes Tin N.L. announced plans to

Table 14.—Tin: World mine production, by country[1]

(Metric tons)

Country	1976	1977	1978[p]	1979[e]
North America:				
Canada	274	328	360	[2]302
Mexico	481	220	73	100
United States	W	W	W	W
South America:				
Argentina[e]	[3]600	[3]500	[3]400	500
Bolivia[4]	[r]30,315	32,626	30,883	[2]27,648
Brazil	[r]5,388	6,450	6,980	8,000
Peru	273	300	1,744	1,500
Europe:				
Czechoslovakia[e]	[3]180	[3]180	[3]180	180
German Democratic Republic[e]	[r]1,300	[r]1,400	1,600	1,600
Portugal	[r]332	267	269	270
Spain	390	554	520	500
U.S.S.R.[e]	31,000	[r]33,000	34,000	35,000
United Kingdom	[r]3,323	[r]4,100	3,132	2,800
Africa:				
Burundi	26	[e]30	[e]30	30
Cameroon	10	14	14	20
Niger	[r]126	130	90	90
Nigeria	3,710	3,267	2,751	3,000
Rhodesia, Southern[e]	[r]600	[r]600	600	600
Rwanda	1,605	1,598	1,502	1,500
South Africa, Republic of	[r]2,799	2,864	2,886	[2]2,697
South-West Africa, Territory of (Namibia)	800	994	[e]1,250	1,000
Swaziland	[r]2	2	1	1
Tanzania	3	--	[e]9	10
Uganda[e]	[3]120	[3]120	[3]120	60
Zaire	3,776	5,073	4,390	4,500
Zambia[e]	([5])	3	([5])	1
Asia:				
Burma	507	362	757	1,160
China, Mainland[e]	20,000	20,000	22,000	25,000
Indonesia	[r]24,456	25,926	27,437	26,000
Japan	643	604	598	600
Korea, Republic of	35	15	20	20
Laos[e]	[3]576	[3]600	[3]400	300
Malaysia	63,401	58,703	62,650	64,000
Thailand	20,452	24,205	31,423	[2]35,353
Vietnam[e]	250	250	250	200
Oceania: Australia	[r]10,611	10,634	11,864	[2]11,400
Total	[r]228,364	235,909	251,183	256,002

[e]Estimate. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.

[1] Contained-tin basis. Data derived in part from the Monthly Statistical Bulletin of the International Tin Council, London, England.

[2] Reported figure.

[3] Estimate by the International Tin Council.

[4] Series revised to reflect reported mine output.

[5] Less than 1/2 unit.

construct a 2,000-ton-per-year smelter, with completion by 1982.

Bolivia.—Tin mine production declined in 1978 and 1979, in spite of record high tin prices. Lower output was attributed to declining ore grades and reserves, high mining costs and taxes, political problems, lack of capitalization, and investment climate. Tin exports, at 29,000 tons, increased 14% in value to $373 million, reflecting record high tin prices; tin exports accounted for 52% of the total value of Bolivian exports and 72% of the value of mineral exports.

Mining costs increased substantially after COMIBOL granted a 35% wage increase to its miners. The private mining sector refused to match COMIBOL's increase, citing that high taxes had eroded profits to such an extent that all it could offer was a 17% wage increase. After the threat of a strike, the Government intervened and ordered the private sector to increase tin miners' wages 20% to 25%. Rail transportation costs also increased significantly after the Antofagasta and Bolivia Railway Co. put into effect a 45% freight rate increase for bulk loads and a 20% increase for minerals in sacks. The increase in rail transportation costs was somewhat mitigated when COMIBOL negotiated a 12% discount for shipments exceeding 3,000 tons per month.

Empresa Minera Catavi, the largest tin mining complex in Bolivia, reportedly lost $9 million in 1978. The loss was attributed to declining ore grade and the use of obsolete equipment. Tin production at the mine has declined over the past 10 years from 6,400 tons to 4,400 tons in 1978. COMIBOL planned to replace the sink-float plant and increase capacity from 5,000 tons per year

Table 15.—Tin: World smelter production, by country[1]

(Metric tons)

Country	1976	1977	1978[p]	1979[e]
North America:				
Mexico[2]	800	1,000	1,000	1,000
United States[3]	[r]5,733	6,724	5,900	[4]4,600
South America:				
Argentina	120	120	120	120
Bolivia[5]	10,100	12,285	16,184	18,000
Brazil	[r]6,252	7,428	7,150	8,000
Europe:				
Belgium	4,068	3,520	3,295	3,000
German Democratic Republic[e]	1,200	1,200	1,200	1,600
Germany, Federal Republic of	1,449	2,897	3,241	3,000
Netherlands	2,000	2,100	1,800	2,000
Portugal	319	588	520	600
Spain	[r]5,369	5,343	[4]4,143	5,000
U.S.S.R.[e]	31,000	[r]33,000	34,000	35,000
United Kingdom	[r]11,161	10,458	8,445	8,000
Africa:				
Nigeria	3,667	3,315	3,045	3,000
Rhodesia, Southern[e]	[r]600	[r]600	600	600
South Africa, Republic of	683	582	637	700
Zaire	478	765	496	500
Asia:				
China, Mainland[e]	20,000	20,000	22,000	25,000
Indonesia	[r]23,322	24,005	25,829	28,000
Japan	1,144	1,280	1,140	[4]1,251
Malaysia[6]	78,017	66,305	71,953	72,000
Thailand	20,337	23,102	28,945	[4]33,058
Vietnam[e]	200	200	200	160
Oceania: Australia	5,603	5,561	5,129	5,000
Total	[r]233,622	232,378	246,972	259,189

[e]Estimate. [p]Preliminary. [r]Revised.

[1] Data derived in part from the Monthly Statistical Bulletin of the International Tin Council, London, England. Output reported throughout is primary tin only unless otherwise specified.

[2] Smelter output from domestic ores is as follows, in metric tons: 1976—481; 1977—220; 1978—73; 1979 (estimated)—100.

[3] Includes tin content of alloys made directly from ores.

[4] Reported figure.

[5] Excludes output of volatilization product (reported as "low grade volatilized powder") as follows, in metric tons: 1976—675; 1977—964; 1978 and 1979—not available.

[6] Includes small production of tin from smelter in Singapore.

to 12,000 tons per year of tin concentrate.

The contract for the construction of a second volatilization plant, to be located at Machacamarca in Oruro, was awarded to the U.S.S.R. The first plant, a $35 million operation under construction by Machinoexport of the U.S.S.R., at La Palca near Potosi, was extensively damaged by a landslide in 1979; the accident delayed by at least 1 year the plant's scheduled opening in September 1979. These volatilization plants were designed to allow the extraction of tin from the slagheaps which have been accumulating since large-scale mining began. Some of the slagheaps were believed to be of better average grades than some of the country's major mines. It was estimated that COMIBOL's tin output could rise by 6,000 tons per year with the opening of the La Palca plant. Similar facilities were planned for mines at Llallagua and Quechisla.

The new smelter at Vinto which can handle low-grade tin concentrate will be built by 1980 adjacent to the main 20,000-ton-per-year smelter which can only handle high-grade concentrates. The new plant was expected to process 25,000 tons of low-grade ore and 5,000 tons yearly of tin dust from the La Palca plant. Together, the two Vinto smelters were expected to be able to handle 30,000 tons of tin, enabling Bolivia to process all of its ore output.

Brazil.—In 1978 and 1979, tin production continued the steady rise of recent years. Production was concentrated in the Federal Territory of Rondonia and the State of Goias. Average production was 0.5 to 1 kilogram of cassiterite per cubic meter of ground. The U.S. Geological Survey estimated measured, indicated, and inferred reserves in the Rondonia tin field as 600,000 tons of tin and an additional 1.07 million tons of material considered to be uneconomic. Brazil's measured tin reserves were about 100,000 tons, half of which were in the Rondonia district. Newly discovered deposits in central Pará were expected to contribute substantially to Brazil's domestic production. The only significant mechanized operations were in Rondonia. Some production from hand mining methods was derived from the Territory of Roraima, Territory of Amapa, and the States of Goias, Pará, Rio Grande do Sul, Paraiba, and Minas Gerais.

The recent rise in tin prices increased exploration activity, resulting in a considerable expansion of measured reserves in Rondonia and, to a lesser extent, in the Xingu area of Pará. The first bucket-wheel suction dredge to be used for mining purposes in Brazil commenced production at the Igarape Preto mine in 1979. Another high-grade gravel pump mine situated to the south of the existing Jacunda mine started production in 1978 and was expected to produce 2,000 tons of concentrate per year when fully operational. One small gravel pump mine in the north of Rondonia was due to start a modest production, and at least two feasibility studies for large bucket-line dredges were in progress.

Patino N.V.'s Brazilian subsidiary, Cia. Estanifera do Brazil (Cesbra), purchased Philipp Brothers' 50% equity in Minera Brasiliense S/A (Mibrasa) for $5 million. Mibrasa operated a washing plant at Santa Barbara and a dredge at Candeias that produced about 100 tons of tin concentrate per month.

A new tin district in the Itamarandiba-Itinga-Ritapolis area in northern Minas Gerais State was being worked by independent prospectors, but was not yet proven commercially exploitable for larger mechanized operations.

Canada.—In 1979, Shell Canada Resources Ltd. announced completion of a diamond drilling program on a tin property in the East Kemptville area of southwest Nova Scotia. The company estimated reserves at 25 million tons of ore containing 0.20% tin to a depth of 100 meters. Further studies were planned for 1980 to evaluate the economic significance of this deposit.

China, Mainland.—China began trial operations at a mine located in Southern Guangxi Autonomous Region. The first phase of the project was designed to process 1 million tons of ore and recover 4,000 tons of tin, 20,000 tons of zinc, 5,000 tons of lead, 3,000 tons of antimony, and 70,000 tons of sulfur, as well as rare and precious metals. The mining area reportedly extended over 100 kilometers and had 800,000 tons of tin reserves.

German Democratic Republic.—A newly developed tin mine and concentrator were brought into operation at Altenberg. Reportedly, the ore deposits were the largest in central Europe. The concentrates were being processed at the modernized tin smelter at Freiberg. Equipment for the new smelter was provided by the U.S.S.R. Tin metal production was expected to increase 45% by 1980.

Indonesia.—The tin industry was dominated by Perusahaan Terbatas Tambang Timah (P. T. Timah), the national tin mining company that produced over 24,000 tons in 1978. Other companies that either produced tin or had exploration rights included P. T. Riau Mining, which was formerly known as Billiton Exploratie Maatschappij Indonesia, B.V. (BEMI); P. T. Broken Hill Pty. Indonesia (BHPI); and P. T. Koba Tin.

P. T. Timah increased its dredge fleet with the commissioning of the $17.8 million Bangka II dredge which is expected to produce about 1,500 tons of tin-in-concentrate per year. Bangka II, the first new dredge commissioned in the past 12 years by P. T. Timah, raised the total number of dredges operating in Indonesia to 35. The company has an additional dredge on order, the Belitung I which, when commissioned in late 1980, was expected to produce about 1,100 tons of tin-in-concentrate per year from offshore deposits near Belitung Island.

P. T. Koba Tin, 75% owned by Australian interests and 25% owned by P. T. Timah, increased production from 153 tons of tin-in-concentrate in 1973 to 2,917 tons of tin-in-concentrate in 1978. Production was expected to reach 4,500 tons per year in the 1980's. P. T. Koba Tin operated two onshore bucket dredges on Banka Island although offshore exploration rights were included in its concession areas.

BHPI was dewatering and rehabilitating the Kelapa Kampit mine on Belitung Island. Production from the $4 million pilot mill totaled 385 tons of tin-in-concentrate in 1978. The Government was evaluating a feasibility study to determine the future of the mine which was abandoned and flooded in World War II.

The new Bima dredge of BEMI, delivered in 1979, was to operate in the Pulau Tudju offshore area in the Riau archipelago. It will be the largest capacity tin dredge in the world, featuring a novel hydraulic support system for its bucket ladder to compensate for expansion.

P. T. Timah's Peltim smelter at Mentok, Bangka, will expand by 1980 from the present capacity of 33,000 tons per year to 39,000 tons per year; an additional reverberatory furnace will be installed to accomodate the anticipated increase in Indonesia's mine production.

Malaysia.—Increased production by the gravel pump sector resulted in successive tin output increases in 1978 and 1979. This marked the first increase in Malaysian production in the past 6 years, but production levels were far below the output of 76,830 tons in 1972. The main factors in the decline of Malaysian production were the restrictive State licensing policy and high taxation.

At yearend 1979, there were 54 tin dredges, 772 gravel pump mines, and 47 opencast, underground, and other miscellaneous mines in operation, about the same as the number of total active mines at yearend 1977. The tin labor force increased slightly to 39,109 workers.

To increase its revenues from tin mining operations, the Selangor State Government revised its policy for granting mining leases. With respect to foreign-owned companies, mining leases would revert to the State upon expiration and would be reissued to the State-owned mining company, Kumpulan Peransang Selangor Bhd. (KPS). KPS would, in turn, sublease the area to the original owner and would collect a tribute. Foreign-owned companies could exploit new mining areas only through a joint-venture company in which KPS held 70% equity. Although Malaysian-owned companies could mine new areas of 202 hectares or greater only through a joint-venture company 51% owned by KPS, no KPS participation would be required to renew leases of any size held by Malaysian companies or for new leases of less than 202 hectares to be mined by a Malaysian company.

Berjuntai Tin Dredging Bhd., the largest Malaysian tin producer and a member of the Malaysian Mining Corp. (MMC), was the first company to be subjected to the new leasing arrangement. Berjuntai leases reverted to KPS upon expiration. KPS subsequently subleased them back to Berjuntai, charging Berjuntai a 10% tribute based on concentrate production.

An agreement between Pacific Tin Consolidated Corp. and KPS resulted in the establishment of a joint-venture firm, Perangsang Pasifik Sdn. Bhd. This company will work 1,250 acres of Pacific Tin's old lease plus an additional 250 acres at Bantang Berjuntai. Pacific Tin, which is 38% owned by Denison Mines Ltd. of Toronto, Canada, operated two dredges in the area and produced about 1.5 million tons of tin concentrates in 1978.

The MMC joined several State Governments in joint mining ventures during the year. The first was an agreement covering the mining of 405 hectares of land near Ayer Kuning in Perak State. The venture between MMC (40%), Tronoh Mines Malaysia Bhd. (30%), and the Perak State Development Corp. (PSDC) (30%) will operate two dredges and is expected to produce about 12,000 tons of tin-in-concentrate from 1981-1996. The land was originally the subject of a 70%-30% joint venture between Tronoh and PSDC which failed to obtain Malaysia's foreign investment committee approval.

Ayer Hitam Tin Dredging Malaysia Bhd., an MMC member operating three dredges in Selangor, studied the feasibility of open pit mining of an area below 67 meters, the maximum dredging depth of its No. 2 dredge. If the results prove favorable, dewatering and stripping of overburden could start in 1980. Ayer Hitam, operating three dredges, produced 2,085 tons of tin concentrate in 1979.

Malaysia announced the planned construction of its first electrolytic tinning line, due to start production by late 1981. It is to be built at Pasir Gudag, a port in Johore and called Malaysian Tinplate Corp. The Government-owned Food Industries of Malaysia will hold a 31% stake, with Mitsui and Kawasaki also participating. This development could absorb substantial amounts of tin that would otherwise be available for export.

Nigeria.—Tin production in Nigeria continued its generally declining trend of recent years. The Nigerian Enterprises Promotion Decree, which requires a 60% Nigerian ownership in all firms mining tin, caused the loss of foreign capital, which in turn has led to declining production, low profitability, declining surface reserves, and the lack of investment in new equipment or mines. Also, the State Governments tended to encourage uses other than mining for the land because of the low revenues received from rent on surface mining leases. The four leading tin producers remained Amalgamated Tin Mines of Nigeria Ltd., Bisichi-Jantar, Ex-Lands, and Gold & Base in the States of Plateau, Benue, Bauchi, and Kano, respectively. Control of Almagamated Tin Mines passed to the Nigerian Government to comply with a Government decree that at least 60% ownership be held by Nigerians; previously a significant portion had been held by the Malaysian Government.

Production by Amalgamated Tin Mines of Nigeria Ltd., the nation's major tin producer, declined successively in 1978 and 1979. The production decline was caused by difficult mining conditions, mechanical troubles, a face fall in one of the mining areas, and sporadic availability of diesel fuel. The company proved an additional reserve block containing 2,700 tons of cassiterite, raising tin ore reserves to 32,500 tons averaging 0.4 kilogram of tin per cubic meter.

For over 50 years, the tin industry in Nigeria has extracted tin ore from surface deposits. Since these deposits are being depleted, the Government is looking into the possibility of exploiting underground deposits. However, a hard core of basalt poses a problem; to penetrate this region, a huge investment in machinery must be made.

Rwanda.—Societe Minera de Rwanda (Somirwa), a 49% Rwandan-51% Belgian firm, began construction of a 3,000-ton-per-year tin smelter at Kigali. The smelter, scheduled for completion in 1980, is expected to handle the nation's entire cassiterite output.

Singapore.—Kimetal Pty. Ltd. began operations at two new tin smelters with a total capacity of 750 tons per month. Singapore has no tin mines and has long been alleged as the center of Southeast Asian tin smuggling activity. A report showed that in 1979 Singapore imported 2,266 tons of tin-in-concentrate and 1,186 tons of metal, yet exports of tin-in-concentrates were 6,121 tons, and of metal, 7,094 tons.[3]

Spain.—Mensa planned to bring onstream by 1980 a tin volatilization plant, to be constructed by Humboldt-Klöckner, at its present Valga works in Galicia. The plant would increase Mensa's smelting capacity to 12,000 tons per year, and enable it to treat material with only 5% metal content compared with its current 45% minimum level.

South Africa, Republic of.—The country's largest producer, Rooiberg Minerals Development Co. Ltd., began construction of a $2 million smelter adjacent to the A mine concentrator. The smelter was expected to produce about 2,000 tons of tin metal per year from Rooiberg's high-grade concentrates. Provisions to smelt the lower grade flotation concentrates will be made later. Most of the metal would be sold domestically.

Thailand.—Tin was the most important metal in the Thai mineral industry, accounting for 78% of the total mineral output value. In response to record high tin prices, Thai tin production has steadily increased in recent years from about 20,000 tons in 1975 to about 35,000 tons in 1979. The major productive sectors were suction boats, 40%; gravel pumps, 31%; and dredges, 18%. In addition to the published production figures, it was estimated that about 2,500 tons of tin concentrates was smuggled out of the country.

A new regulation on foreign investment in Thailand, effective December 1978, required that mining companies with offshore operations in less than 61 meters of water must be 60% Thai-owned, and those with operations in depths in excess of 61 meters must have at least 51% Thai ownership. The regulation also provided the right of the Thai Government's Offshore Mining Organization (OMO) to purchase up to 10% of the shares at par value in foreign companies operating in Thailand.

OMO expected delivery of its first dredge in 1980. The dredge will have a capacity of 329,000 cubic meters per month and work offshore deposits at Ban Do Dan, Phangnga.

Aokan Tin Bhd.'s production from its two dredges operating in Phuket Bay was 1,668 tons of tin concentrates in 1979. After Aokam Tin agreed to a reorganization of the company as Aokam Thai Ltd. in which Aokam Tin will hold 40% and Thai interests 60% equity, the Thai Government renewed Aokam Tin's mining leases in Phuket Bay for another 25 years. Aokam Tin, a MMC company, will sell its mining assets and Thai mining leases to Aokam Thai for $15.25 million. Aokam Tin's affiliated company, Tongkah Harbour Tin Dredging Bhd., was also negotiating with the Thai Government to establish a Thai operating company. Discussions were slower because Tongkah Harbour's leases did not expire until 1980 compared with December 31, 1978, for Aokam Tin.

Thai Pioneer Enterprise Ltd. planned to build a $7.2 million tin smelter at Pathum Thani. Lurgi Chemie and Huttentechnik GmbH will equip the smelter. Metallgesellschaft AG will train Thai operating personnel at its Berzelius plant and sell the tin on world markets. The plant, scheduled to begin production in 1980, will produce 3,600 tons per year with production expected to increase to 5,200 tons per year within 5 years.

The Thai Present Co.'s smelter, planned for the Phuket area, will have a 7,000-ton-per-year capacity, with concentrates coming from the Andaman Sea region.

The Thailand Smelting and Refining Co. Ltd. (Thaisarco) began the addition of two furnaces to double capacity. Thaisarco, Thailand's only tin smelter, produced 28,945 tons of metal in 1978.

United Kingdom.—Cornwall Tin & Mining Corp.'s Mt. Wellington mine, which began commercial operations in May 1976 after 8 years of prospecting and development, closed down in April 1978 because the ore grade was not at projected levels. The closure of the mine caused the adjacent Wheal Jane mine, a Consolidated Gold Fields Ltd. mine in operation since 1971, to close due to the influx of water from the Mt. Wellington mine and the marginal viability of Wheal Jane. The two mines, which produced 1,400 tons of tin-in-concentrate in 1977, remained closed through most of 1978 and all of 1979, as several prospective purchasers studied the feasibility of reopening them. In July 1979, Rio Tinto Zinc, through its 95%-owned Carnon Consolidated, purchased the two mines with an indication of restarting production by 1980.

Geevor Tin Mines Ltd. mined 119,088 tons of tin ore in 1979; however the grade was lower than in recent years, falling to 8.83 kilograms per ton. A subincline project to gain access to the lower levels of the abandoned Levant mine that adjoins Geevor was completed; the reserves in this part of the mine were estimated at 250,000 tons containing 1% tin oxide. The firm expected to commence production there in 1981.

Joint partners AMAX Exploration and Hemerdon Mining & Smelting continued exploration of the Hemerdon Ball tin-tungsten-china clay ore body near Plymouth, Devon. Through the end of 1979, exploration indicated a mineralization of about 45 million tons at 200 meters, with an average grade of 0.025% tin. Determination of the commercial viability of the prospect was expected by 1982.

Europe's largest tin smelter, Capper Pass, located at Hull, was inactive for about a month in 1978 due to a labor dispute. The Rio Tinto Zinc subsidiary was responsible for the entire United Kingdom output of refined tin as well as processing concentrates for Australia and Bolivia.

TECHNOLOGY

The Southeast Asian Tin Research and Development Center (SEATRAD), established by an international agreement between Indonesia, Malaysia, and Thailand in 1977 to coordinate research on tin prospecting, mining, beneficiation, and smelting, was granted $2.6 million towards its operating expenses for 1978-81 by the United Nations Development Program. SEATRAD's initial program includes (1) the development of new and improved drilling techniques and improved hydraulic mining techniques in Malaysia, (2) exploration in two areas of Thailand, and (3) studies on slag treatment in Indonesia.[3]

A full-scale version of a laboratory mineral separator was installed at Cornwall's largest tin mine, South Crofty, to evaluate its efficiency in reclaiming very fine tin ores.[4] The laboratory separator could recover tin from sands containing as little as 0.2% tin.

A paper describing the technical feasibility of the sodium sulfide leaching-electrowinning process for recovering tin from volatilized dusts was published.[5] The dusts were leached in a sodium hydroxide-sodium sulfide solution which was cooled to remove the crystallized arsenic compound. The electrowinning process, using a solution of sodium hydroxide and sodium sulfide, permitted the application of high current densities, yielding cell efficiencies of over 95%. The process may be installed immediately after the fuming operation, eliminating the smelting steps.

A new method for recovering metals from dilute solutions using a fluidized bed of 500-millimeter-diameter glass beads in combination with screen-like expanded mesh electrodes was developed.[6] The glass-bead bed was fluidized by a dilute metal-containing solution. The resultant vigorous mixing, which optimized contact between the dissolved metal and the electrode, improved the mass transfer. Once the electrodes became saturated with plated-out metal, they were removed from the unit and processed for recovery of the metal. Although already tested by recovering copper, cadmium, nickel, and zinc from plating-plant rinse tanks with concentrations typically from 100 to 220 parts per million, more expensive metals, such as tin, could be processed in lower concentrations.

It was found that the presence of tin in cracking catalysts counteracts the loss of activity and selectivity of catalysts in refineries which is caused by the presence of heavy metals in feedstock.[7] The only previously known additive that had the same effect was an antimony compound. The problem of feed materials containing heavy metals has been the focus of considerable research as refiners anticipate dealing with lower grade stocks.

A process to recycle nuclear fuel was developed using a bath of molten tin held in graphite vessels at low pressure in an inert-gas atmosphere.[8] The molten oxides of the metals in the fuel are reduced to metals and nitrided. Waste products, which are about 3% of the fuel, separate either as a gas or as a solid floating precipitate. The gas can be condensed and stored. Uranium and plutonium nitrides, the reusable fuel components that make up 97% of spent fuel, sink to the bottom of the vessel and can be recovered and refabricated into fuel rods. The new process reportedly could reduce nuclear waste volume thirtyfold and yield a solid waste that is easier to store.

Study by the U.S. Bureau of Mines has shown that it is possible to recover significant quantities of steel scrap and tin from urban waste materials.[9] The research indicated that by carefully processing municipal solid waste by a series of leaching, shredding, and magnetic separation steps, it is possible to produce carload quantities of detinned bales of steel scrap equivalent to No. 1 bundle quality for use in steelmaking. In addition, up to 5 pounds of tin per gross ton of scrap is recovered during the detinning process.

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[1] Physical scientist, Section of Nonferrous Metals.

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[3] Tin International. S. E. Asian Tin R & D. V. 51, 1978, p. 484.

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[7] Chemical Week. Technology Newsletter. V. 124, No. 2, Jan. 10, 1979, p. 25.

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Titanium

By Langtry E. Lynd[1] and Ruth A. Hough[2]

The years 1978 and 1979 were outstanding ones for titanium, with U.S. mill product shipments reaching a new record each year. In 1979, the sponge metal production rate was approaching estimated industry capacity of about 23,000 tons per year.[3] The main factor in the strong market for titanium metal was the greatly increased rate of orders for commercial airliners. Demand was such that lead times for mill product deliveries rose to 70-80 weeks or more, compared with 12-24 weeks in 1977. Domestic production and consumption of titanium dioxide pigment products increased moderately in both 1978 and 1979. Production of ilmenite and rutile decreased considerably in 1978, mainly because of mine shutdowns at Lakehurst, N.J., and Green Cove Springs, Fla. However, ilmenite production rebounded in 1979 to about the 1977 level, despite the November 1979 closure of a mine at Boulougne, Fla.

Prices for titanium mineral concentrates except ilmenite, and for titanium products increased in 1978 and 1979, especially those for rutile concentrate, titanium pigment, and sponge metal, which rose about 60%, 20%, and 35%, respectively.

Legislation and Government Programs.—The Government stockpile goal for titanium sponge metal remained at 131,503 tons during 1978 and 1979. The quantity of specification titanium sponge metal in the Government stockpile in December 1979 was 21,465 tons. In addition, there was 10,866 tons of nonspecification material.

Table 1.—Salient titanium statistics

	1975	1976	1977	1978	1979
United States:					
Ilmenite concentrate:					
Mine shipments ---------short tons--	702,252	617,886	542,333	580,878	646,399
Value ---------------thousands--	$26,946	$27,578	[r]$25,201	$25,628	$32,965
Imports -------------short tons--	122,010	168,402	334,990	308,671	184,478
Consumption-----------------do--	747,821	822,259	866,504	792,289	791,063
Titanium slag:					
Imports --------------------do--	212,682	171,624	150,564	149,172	111,210
Consumption-----------------do--	147,965	203,964	149,454	128,826	144,708
Rutile concentrate, natural and synthetic:					
Imports --------------------do--	224,499	281,712	123,800	289,617	283,479
Consumption-----------------do--	231,430	287,718	185,419	263,184	313,761
Sponge metal:					
Imports for consumption ------do--	4,190	1,778	2,387	1,476	2,488
Consumption-----------------do--	17,626	13,315	16,236	19,854	23,937
Price, Dec. 31, per pound-----------	$2.70	$2.70	$2.96	$3.28	$3.98
Titanium dioxide pigments:					
Production -----------short tons--	603,429	712,940	687,103	700,755	724,887
Imports for consumption ------do--	25,918	68,497	114,810	117,708	104,968
Apparent consumption--------do--	595,516	753,947	785,003	801,728	810,218
Price, Dec, 31, cents per pound:					
Anatase -----------------------	38.5	41.0	43.5	46.0	53.0
Rutile ------------------------	43.5	46.5	48.5	51.0	59.0
World production:					
Ilmenite concentrate -------short tons--	3,194,028	[r]3,490,031	[r]3,653,264	[p]3,861,397	[e]3,848,714
Titanium slag ---------------do--	831,505	[r]901,198	[r]764,514	[p]1,037,198	[e]856,040
Rutile concentrate, natural---------do--	[1]421,532	[r][1]444,806	[r][1]380,833	[p][1]331,951	[e][1]398,173

[e]Estimate. [p]Preliminary. [r]Revised.
[1]Excludes U.S. production data to avoid disclosing company proprietary data.

The Government stockpile goal for rutile concentrate remained at 173,928 tons, and total rutile stockpile inventory in December 1979 was 39,186 tons.

In September 1978, the U.S. Department of the Treasury received a complaint from SCM Corp. alleging that titanium dioxide imported into the United States from Belgium, the Federal Republic of Germany, France, and the United Kingdom was being sold at less than fair value. Investigations carried out by the Treasury Department under the Antidumping Act of 1921, as amended, resulted in the determination that such sales at less than fair value had taken place. However, investigations by the International Trade Commission to determine the extent of any injury to a U.S. industry from these sales at less than fair value resulted in a determination in November 1979 that no such injury had occurred or was likely to occur.[4]

The Federal Trade Commission (FTC) in April 1978 charged E. I. du Pont de Nemours and Co., Inc., with attempting to monopolize the production of titanium dioxide pigments and engaging in unfair methods of competition. In September 1979, an administrative law judge for the FTC dismissed these allegations,[5] and an FTC hearing officer ruled that the agency should drop its charges against the company.

A Federal grand jury in Pittsburgh, Pa., in September 1978 indicted four producers of titanium mill products, and some of their officers, on price-fixing charges. The trial and sentencing were completed in May 1979. One individual pleaded guilty and the other eight defendants pleaded nolo contendere. The defendant companies in the trial were Martin Marietta Aluminum, Inc., RMI Co., Crucible, Inc., and Lawrence Aviation Industries, Inc. Titanium Metals Corporation of America (TMCA) was named as an unindicted coconspirator. A civil suit filed by the U.S. Justice Department against all these companies was still pending at the end of 1979.[6]

In efforts to alleviate the shortage of titanium by encouraging imports, the following two bills were introduced in 1979: H.R. 3591, on April 10, to reduce temporarily the duty on titanium sponge, from 18% to 9% ad valorem, until June 30, 1981; and H.R. 4738, on July 11, to reduce temporarily the duty on titanium sheet, plate, and other rolled titanium products, from 18% to 9% ad valorem, until June 30, 1981. Under the Tokyo Round of negotiations completed in 1979, the most-favored-nation duty on the above forms of titanium was scheduled to be reduced in several stages to 15%, over the period January 1, 1980, to January 1, 1987. The suspension of duty on waste and scrap titanium was extended until June 30, 1981, as provided by Public Law 95-508. The duty on titanium dioxide, 7.5% ad valorem, most-favored-nation, was not affected by the Tokyo negotiations.

H.R. 2297 was introduced on February 21, 1979, to continue until June 30, 1982, the existing suspension of duties on synthetic rutile.

DOMESTIC PRODUCTION

Concentrates.—Production of ilmenite decreased in 1978 for the fifth consecutive year, but reversed the trend in 1979 by rebounding to near the 1977 production level. The decrease in 1978 was caused mainly by the shutdown, because of depleted reserves, of the SCM Corp. sand mining operation near Lakehurst, N.J., in March 1978. The increased production in 1979 was achieved despite the shutdown of the Titanium Enterprises (TE) mining and wet milling facilities at Green Cove Springs, Fla., in June 1978. However, TE continued operation of its dry mill, producing some ilmenite as well as zircon and monazite from stockpiled tailings. In November 1979, Humphreys Mining Co. ceased operations at its Boulougne, Fla., deposit because of depleted reserves. Production at the mines of Du Pont at Starke, and Highland, Fla., and of ASARCO, Incorporated, at Manchester, N.J., was comparable to their 1977 output. Production by NL Industries, Inc., Tahawus, N.Y., was over 50% higher in 1979 than in 1977 or 1978. Production of rutile concentrate has been insignificant since the TE mine shutdown in June 1978. The other Florida producers recovered some rutile in bulk concentrates consisting mainly of ilmenite and leucoxene.

In April 1980, the TE property was purchased by Associated Minerals Consolidated, Ltd. (AMC) of Australia for $11.7 million. AMC expected to produce at Green Cove Springs, over the next 16 years, 50,000 tons per year of ilmenite, 25,000 tons per year of rutile, and 25,000 tons per year of zircon, as well as smaller amounts of leu-

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Table 2.—Production and mine shipments of ilmenite concentrates[1] from domestic ores in the United States

Year	Production gross weight (short tons)	Shipments		
		Gross weight (short tons)	TiO_2 content (short tons)	Value (thousands)
1975	717,281	702,252	404,269	$26,946
1976	652,404	617,896	374,989	27,578
1977	638,503	542,333	331,139	25,201
1978	589,751	580,878	252,842	25,628
1979	639,292	646,399	389,535	32,965

[1] Includes a mixed product containing rutile, leucoxene, and altered ilmenite.

Table 3.—Components of U.S. titanium metal supply and demand

(Short tons)

	1975	1976	1977	1978	1979
Production:					
Ingot	25,560	21,614	26,302	31,385	37,125
Exports:					
Sponge	NA	NA	NA	97	180
Other unwrought	NA	NA	NA	210	155
Scrap	4,326	6,144	3,394	5,453	4,967
Ingot, slab, sheet bar, etc	1,900	1,065	1,050	1,340	1,984
Other wrought	--	--	--	689	1,316
Total	6,226	7,209	4,444	7,789	8,602
Imports:					
Sponge	4,190	1,778	2,387	1,476	2,488
Scrap	876	1,860	4,494	3,789	6,154
Ingot, billet	209	323	354	561	338
Mill products	--	--	--	1,125	942
Total	5,275	3,961	7,235	6,951	9,922
Stocks, end of period:					
Government- Sponge (total inventory)	31,692	32,329	[r]32,331	32,331	32,331
Industry -					
Sponge	5,669	3,617	3,546	2,642	2,155
Scrap	6,132	5,764	[r]6,770	6,447	6,733
Ingot	[r]1,012	1,831	1,898	2,155	2,221
Other	35	26	42	73	200
Total industry	12,848	11,238	12,256	11,317	11,309
Reported consumption:					
Sponge	17,626	13,315	16,236	19,854	23,937
Scrap	8,316	9,211	10,889	12,318	13,986
Ingot	24,486	21,004	25,241	30,746	35,440
Mill products (net shipments)[1]	15,628	14,498	15,466	17,648	21,122
Castings (shipments)[1]	241	257	188	180	184

[r] Revised. NA Not available.

[1] Source: Bureau of the Census, Current Industrial Reports Series DIB-991 and ITA-991.

coxene, staurolite, and monazite.

Kerr-McGee Chemical Corp. suspended operations at its synthetic rutile plant at Mobile, Ala., on March 1, 1978, to investigate process and design modifications. The modifications were reportedly needed to allow the plant to operate at design capacity of 110,000 tons per year and be in compliance with environmental regulations. In late 1979 it was announced that this synthetic rutile plant will resume operations, and by mid-1980 should be able to supply the raw material requirements for Kerr-McGee's pigment plant in Hamilton, Miss. Total employment at the synthetic rutile plant was to be 113 people.

A comprehensive study was completed by the State of Minnesota on the copper, nickel, and titanium resources of the Duluth Complex in St. Louis and Lake Counties, Minn. Titanium resources in the area were estimated at more than 220 million tons of magnetite-ilmenite ore containing over 10% TiO_2.[7]

U.S. Titanium Corporation, a New York firm, was reportedly planning to mine the

Piney River, Va., titanium deposit formerly owned by American Cyanamid Corp. to recover ilmenite for pigment manufacture, and calcium phosphate for fertilizer production. U.S. Titanium in 1978 agreed to pay $9,240 for replacement of Piney River fish that were killed in 1977 by runoff from waste copperas (ferrous sulfate), which was left on the property from the previous pigment manufacturing operation. U.S. Titanium also agreed to remove the copperas, estimated at 60,000 to 100,000 tons[8], and in January 1980 was ordered by a Virginia judge to pay $100,000 into an escrow account to cover the costs of removal, and to complete removal of the waste by December 31, 1980.[9]

Ferrotitanium.—Ferrotitanium was produced by Shieldalloy Corp. at Newfield, N.J., by the Pesses Co. at Solon, Ohio, and by Reactive Metals and Alloys Corp., West Pittsburg , Pa. Most of the production consisted of the 70% titanium grades.

Metal.—Production of titanium sponge metal in 1978 was 29% higher than in 1977, and in 1979 was 24% higher than in 1978.

Oregon Metallurgical Corp. rebuilt its titanium sponge metal plant which had been severely damaged by an explosion and fire in October 1977, and resumed production in March 1978. The production rate in 1979 was expected to be close to full capacity.

Sponge producing companies during 1978 and 1979 and their approximate annual capacities were TMCA, Henderson, Nev., jointly owned by NL Industries, Inc., and Allegheny-Ludlum Steel Corp., 13,000 tons; RMI Co., Ashtabula, Ohio, owned by National Distillers & Chemical Corp. and United States Steel Corp., 7,500 tons; and Oregon Metallurgical Corp., Albany, Oreg., publicly owned with Armco Steel Corp. and Ladish Corp. as major stockholders, 2,500 tons. The following eight companies produced titanium ingot:

Company	Plant location
Crucible, Inc., Colt Industries	Midland, Pa.
Howmet Corp., Alloy Div	Whitehall, Mich.
Lawrence Aviation Industries, Inc	Port Jefferson, N.Y.
Martin Marietta Aluminum, Inc	Torrance, Calif.
Oregon Metallurgical Corp.	Albany, Oreg.
RMI Co	Niles, Ohio.
Teledyne Allvac	Monroe, N.C.
Titanium Metals Corp. of America	Henderson, Nev.

The high demand for titanium metal which began in 1978 and intensified in 1979 led to sponge production rates close to industry capacity, and influenced sponge producers to begin expansion programs. RMI Co. announced it would expand its sponge capacity to 9,000 tons per year, the additional 1,500 tons of annual capacity to be in operation by mid-1980. RMI also began a 25% expansion of its ingot and mill product production capacity. TMCA's TIMET Division announced a 1,000-ton-per-year sponge capacity expansion to 14,000 tons per year, to be completed in late 1980 or early 1981, with further expansion to 16,000 tons per year likely in 1982-84. Oregon Metallurgical Corp. was considering a 50% expansion of sponge capacity to 3,750 tons per year.

Dow Chemical Co. and Howmet Turbine Components Corp. announced formation of a jointly owned firm, D-H Titanium Co., to scale up and commercialize an electrolytic process for the production of titanium sponge.[10] This process is based on work initiated by the Bureau of Mines during the 1960's and subsequent research conducted by Dow. Pilot plant work by Howmet reportedly indicated that unit process energy costs are about one-half those of existing commercial processes. Plans were completed for the construction of an expandable semicommercial manufacturing unit in Freeport, Tex., with startup scheduled for 1980. If this effort to develop a commercial prototype operation is successful, a commercial-scale plant, probably with about 5,000 tons per year capacity, was planned to be onstream by the mid-1980s.[11]

Pigment.—Pigment production increased in 1978 and 1979 compared with 1977. Rutile pigment accounted for 78% and 74% of total production in 1978 and 1979, respectively, and was produced by six manufacturers. Five companies produced anatase pigment. Companies producing titanium dioxide pigment during 1978-79, with plant location and estimated capacity at yearend 1979, in tons per year, were as follows:

Company and plant location	Pigment capacity (tons per year)	
	Sulfate process	Chloride process
American Cyanamid Co., Savannah, Ga	52,000	40,000
E. I. du Pont de Nemours & Co., Inc.:		
Antioch, Calif	--	35,000
De Lisle, Miss	--	150,000
Edge Moor, Del	--	167,000
New Johnsonville, Tenn	--	228,000
Kerr-McGee Chemical Co., Hamilton, Miss	--	52,000
NL Industries, Inc., Sayreville, N.J	100,000	--
Gulf + Western Natural Resources Group, Chemicals Div. (formerly New Jersey Zinc Co.):		
Ashtabula, Ohio	--	29,000
Gloucester City, N.J	44,000	--
SCM Corp., Glidden Pigments Group, Chemical/Metallurgical Div.:		
Ashtabula, Ohio	--	42,000
Baltimore, Md	53,000	30,000
Total	249,000	773,000

Du Pont completed construction of its 150,000-ton-per-year chloride process pigment plant at DeLisle, Miss. Production began in late 1979 and was to be increased gradually as demand grows.

Early in 1978, NL Industries Inc. ceased production of pigment from concentrates at its St. Louis, Mo., plant, restricting its output at that location to pigment slurry made from pigment manufactured at other plants. The company's decision was said to be based on market considerations and environmental compliance costs. The St. Louis plant was closed permanently in 1979.

In May 1979, NL Industries announced the combination of its Industrial Chemicals Div. and its Worldwide Titanium Pigment Group into one operational unit, to be known as NL Chemicals, with headquarters in Hightstown, N.J.

In December 1979, it was reported that Glidden Pigments Group of SCM Corp. was planning to expand TiO_2 pigment production capacity by up to 20,000 tons at its Ashtabula, Ohio, and Baltimore, Md., plants.

In August 1979, two producers of sulfate process pigment reported arrangements for the sale of byproduct gypsum from their waste acid neutralization plants. Gypsum from American Cyanamid Co.'s Savannah, Ga., plant was to be converted by an adjacent Lemco, Inc., plant into briquettes for use by the cement industry. SCM Corp. was selling byproduct gypsum from its Baltimore, Md., plant to a local wallboard manufacturer.

The use of TiO_2 pigment in slurry form continued to grow. Slurry shipments reportedly doubled in 5 years to an estimated 145,000 tons in 1978, or 20% of total U.S. pigment production.

Table 4.—Components of U.S. titanium dioxide pigment supply and demand

(Short tons)

	1975	1976	1977	1978	1979[p]
Production	608,429	712,940	[r]687,103	700,755	724,887
Shipments: [1]					
Quantity	576,097	711,774	696,552	714,547	NA
Value (thousands)	$423,701	$594,846	$602,383	$621,909	NA
Imports	25,918	68,497	114,810	117,706	104,968
Exports	15,807	20,580	16,336	37,812	49,369
Stocks, end of period	[r]106,963	[r]113,878	[r]114,447	93,370	63,638
Apparent consumption[2]	595,516	753,947	785,003	801,728	810,218

[r] Revised. [p] Preliminary. NA Not available.

[1] Includes interplant transfers.

[2] Apparent consumption = production plus imports minus exports minus stock increase.

Source: U.S. Bureau of the Census.

CONSUMPTION AND USES

Concentrates.—The total amount of TiO_2 consumed domestically in concentrates increased from 801,000 tons in 1977 to 886,000 tons in 1979. During that period, the market share of TiO_2 in ilmenite dropped from 65% to 55%, that of TiO_2 in slag dropped from 13% to 12%, while the proportion of TiO_2 consumed as rutile increased from 22% to 33%. This increase in rutile consumption was partly due to Kerr-McGee's return to using natural rutile following shutdown of its beneficiated ilmenite (synthetic rutile) plant in 1978.

NL Industries developed a well-drilling mud based on ilmenite and in 1979 was marketing an ilmenite product for this application. Advantages of ilmenite over barite, which is used in conventional drilling muds, include higher density and durability, and lower viscosity at a specified mud density. About 2.5 million tons of barite was used in domestic drilling muds in 1979.

Metal.—Increased demand was reported for all mill product categories in 1978 and 1979, except for a 9% to 10% drop in shipments of sheet, strip and plate, and pipe and tubing, in 1978. The strong market was due mainly to a sharply increased rate of ordering for commercial aircraft such as the Boeing 747, Lockheed L1011, and McDonald-Douglas DC10 in 1978, and to peaking of demand for commercial airframes, military programs, and tubing for nuclear powerplant condensers in 1979. Titanium tubing for desalination units to be installed in the Middle East was also a major application in 1979.

Factors influencing demand were the placing of orders by large aerospace firms to fill both actual requirements and anticipated new orders, and the need for producers, fabricators, and users to build larger work-in-process inventories.[18] As a result of this heavy demand, a shortage of titanium metal developed in 1978 and continued through 1979, with delivery lead times for mill products rising to 70-80 weeks compared with 12-24 weeks in 1977. A reduction of demand during 1980 was expected by some industry sources, which along with increased domestic production and imports may ease the shortage by late 1980 or early 1981.

It was estimated that in 1978 and 1979 consumption of titanium mill products, allowing for the scrap generated and used for making steel and other alloys, was about 60% for aerospace uses, 20% for powerplant and chemical industry application, and 20% for alloying purposes. Neglecting the scrap generated, mill products usage was about 75% for aerospace and 25% for other industrial uses.

The main nonaerospace industrial applications of titanium in 1978 and 1979 were as pipe and tubing for surface condensers in powerplants, for heat exchangers in the chemical industry, and for desalination evaporators; as sheet and strip for titanium electrodes, chiefly anodes for production of chlorine and sodium chlorate; as plate, pipe,

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Table 5.—Consumption of titanium concentrates in the United States, by product

(Short tons)

Year and product	Ilmenite[1]		Titanium slag		Rutile	
	Gross weight	TiO_2 content[e]	Gross weight	TiO_2 content[e]	Gross weight	TiO_2 content[e]
1975	747,821	432,409	147,965	104,585	231,430	218,923
1976	822,259	498,013	203,964	144,506	237,718	223,612
1977	[2]866,504	[2]521,194	149,454	106,201	[3]185,419	[3]173,840
1978:						
Alloys and carbide	(4)	(4)	(5)	(5)	(4)	(4)
Pigments	781,241	467,410	128,826	91,490	209,743	195,431
Welding-rod coatings and fluxes	(4)	(4)	--	--	8,979	8,427
Miscellaneous[6]	11,048	8,038	--	--	44,462	41,326
Total	792,289	475,448	128,826	91,490	263,184	245,184
1979:						
Alloys and carbide	(4)	(4)	(5)	(5)	(4)	(4)
Pigments	775,681	475,342	144,708	106,346	247,334	230,776
Welding-rod coatings and fluxes	(4)	(4)	--	--	10,480	9,947
Miscellaneous[6]	15,382	11,886	--	--	55,947	52,189
Total	791,063	487,228	144,708	106,346	313,761	292,912

[e] Estimate.

[1] Includes a mixed product containing rutile, leucoxene, and altered ilmenite.

[2] Includes estimate of imported ilmenite used to make synthetic rutile in the United States.

[3] Includes imported synthetic rutile, but excludes synthetic rutile made in the United States from imported ilmenite.

[4] Included with "Miscellaneous" to avoid disclosing company proprietary data.

[5] Included with "Pigments" to avoid disclosing company proprietary data.

[6] Includes ceramics, chemicals, glass fibers, and titanium metal.

Table 6.—Distribution of titanium-pigment shipments, titanium dioxide content, by industry

(Percent)

Industry	1975	1976	1977	1978	1979
Paints, varnishes, lacquers	58.7	51.1	52.0	47.9	47.4
Paper	19.0	21.4	20.7	20.8	21.8
Plastics (except floor covering and vinyl-coated fabrics and textiles)	7.4	10.6	11.7	11.6	11.8
Rubber	2.8	2.7	3.1	2.8	2.9
Ceramics	1.9	1.9	1.9	2.1	1.9
Other	7.6	9.4	8.2	8.7	9.0
Exports	2.6	2.9	2.4	6.1	5.2
Total	100.0	100.0	100.0	100.0	100.0

and tubing for chemical process equipment; and in miscellaneous applications including marine, and steam turbines.[13]

Pigment.—Pigment consumption increased only about 3% from 1977 to 1979, despite a 6% increase in production during that period. Titanium dioxide long-term growth outlook was estimated by major producers at 2% to 3% per year.[14]

Ferrotitanium.—Consumption of ferrotitanium and titanium metal scrap in steel and other alloys increased about 6% in 1979, mainly because of a 61% increase in the amount used in superalloys. A projection was made in 1979 that increased production of high strength steels from about 5 million tons to 10 million tons annually by the 1980s could require an additional 600 to 700 tons per year of titanium additives.[15]

Table 7.—Consumption of titanium products[1] in steel and other alloys

(Short tons)

	1975	1976	1977	1978	1979
Carbon steel	804	976	780	601	529
Stainless and heat-resisting steel	1,117	2,008	2,049	2,394	2,399
Other alloy steel (includes HSLA)	838	818	859	936	928
Tool steel	W	W	W	W	W
Total steel[2]	2,759	3,802	3,688	3,931	3,856
Cast irons	96	100	92	144	129
Superalloys	585	455	482	743	1,197
Alloys, other than above	1,548	768	537	255	234
Miscellaneous and unspecified	182	273	r16	9	9
Total consumption	5,170	5,398	r4,815	5,082	5,425

rRevised. W Withheld to avoid disclosing company proprietary data; included in "Miscellaneous and unspecified."

[1] Includes ferrotitanium containing 20% to 70% titanium and titanium metal scrap.

[2] Except for data withheld and for unspecified included under "Miscellaneous and unspecified."

STOCKS

Stocks of titanium concentrates in the United States are shown in table 8.

Table 8.—Stocks of titanium concentrates in the United States, December 31

(Short tons)

	Gross weight	TiO_2 content[e]
Ilmenite:		
1977	r805,020	r494,558
1978	e810,757	510,430
1979	728,620	462,217
Titanium slag:		
1977	r62,581	r44,464
1978	105,685	75,097
1979	75,089	56,917
Rutile:		
1977	r146,200	r136,985
1978	e183,793	172,685
1979	e127,453	120,070
Titanium pigment:[1]		
1977	NA	114,467
1978	NA	93,370
1979	NA	63,638

eEstimate. rRevised. NA Not available.

[1] Source: U.S. Bureau of the Census.

PRICES

Concentrates.—Price quotations for ilmenite in domestic markets, $55 per long ton at the beginning of 1978, decreased to $50 in August 1978 and remained at that level until December 1979 when they increased to $55 per long ton. Australian ilmenite prices increased from $17-$19 per long ton in 1978 to $18-$19 per long ton f.o.b. Australian ports in January 1979, at which level they closed the year.

Rutile concentrate spot prices, f.o.b. Atlantic and Great Lakes ports, rose from $300-$325 per short ton to $325-$350 in August 1978, to $350-$375 in January 1979, to $375-$400 in June 1979 and to $425-$450 per short ton at yearend. Australian rutile, f.o.b. Australian ports, began 1978 at $185-$195 per short ton, increased in November 1978 to $230-$250, further increased in August 1979 to $348-$369, and ended the year with prices of $291-$332 for bulk lots and $322-$352 per short ton for bagged lots. Declared valuations of synthetic rutile imports at foreign ports of shipment averaged $151 for 1978 and $162 for 1979, while c.i.f. values averaged $169 for 1978 and $181 for 1979 per short ton.

The price of titanium slag, f.o.b. Sorel, Quebec, increased in March 1978 from $102.50 per long ton to $110 per long ton, where it remained through the end of 1979.

Metal.—The published price of domestic titanium sponge climbed in September 1978 from $2.98 per pound to $3.28 per pound, to $3.98 per pound in March 1979, and remained at that level through the rest of the year. Japanese sponge increased from $2.50-$2.65 per pound to $2.80-$2.95 at the start of 1978, to $3.10-$3.30 in August 1978 and to $3.60 per pound in January 1979, where it remained through yearend. Quotations for mill products, per pound, during the period were bar, $7.48 to $10.73; billet, $4.86 to $7.13; plate $6.50 to $9.04; and sheet and strip, $11.90 to $14.10.

Pigment.—Published prices of titanium dioxide pigment in January 1978 were 48.5 cents per pound for rutile and 43.5 cents per pound for paper-grade anatase, and were raised periodically to the following levels, for rutile and anatase, respectively: Second quarter 1978, 51.0 cents and 46.0 cents per pound; second quarter 1979, 54.5 cents and 49.5 cents per pound; and third quarter 1979, 59.0 cents and 53.0 cents per pound.

FOREIGN TRADE

Exports and imports of titanium materials are shown in tables 9 through 12.

Table 9.—U.S. exports of titanium products, by class

Class	1976		1977		1978		1979	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Concentrates:								
Ilmenite	3,478	$78	21,876	$415	NA	NA	NA	NA
Rutile	1,324	399	803	328	NA	NA	9,908	$2,057
Total	4,802	477	22,679	743	NA	NA	9,908	2,057
Metal:								
Sponge	--	--	--	--	97	$351	180	1,019
Other unwrought	--	--	--	--	210	1,141	155	1,125
Scrap	6,144	8,547	3,394	5,643	5,453	8,777	4,967	18,265
Ingots, billets, slabs, etc	1,065	15,039	1,050	14,254	1,340	11,290	1,984	26,456
Other wrought	NA	NA	NA	NA	689	11,768	1,316	25,912
Total	7,209	23,586	4,444	19,897	7,789	33,327	8,602	72,777
Pigment and oxides:								
Titanium dioxide pigments	20,555	16,155	16,225	12,506	37,812	26,967	49,369	43,940
Titanium compounds except pigment grade	25	74	111	122	1,529	2,505	2,087	4,211
Total	20,580	16,229	16,336	12,628	39,341	29,472	51,456	48,151

NA Not available.

Table 10.—U.S. imports for consumption of titanium concentrates, by country[1]

Country	1977 Quantity (short tons)	1977 Value (thousands)	1978 Quantity (short tons)	1978 Value (thousands)	1979 Quantity (short tons)	1979 Value (thousands)
Ilmenite:						
Australia	309,902	$4,590	308,649	$4,463	184,478	$2,846
Netherlands[2]	25,088	1,087	--	--	--	--
Norway	--	--	22	3	--	--
Total	334,990	5,677	308,671	4,466	184,478	2,846
Titanium slag:						
Canada	150,564	13,514	149,172	14,858	81,289	7,814
South Africa, Republic of	--	--	--	--	29,921	3,286
Total	150,564	13,514	149,172	14,858	111,210	11,100
Rutile, natural:						
Argentina[2]	7,862	1,789	--	--	--	--
Australia	88,681	18,659	242,505	45,667	140,291	25,307
Netherlands[2]	673	489	--	--	--	--
Sierra Leone	--	--	--	--	7,980	1,484
South Africa, Republic of	--	--	5,453	841	10,819	2,068
Sri Lanka	--	--	6,063	990	6,305	1,482
Other	23	3	8	1	18	113
Total	97,239	20,940	254,029	47,499	165,413	30,454
Rutile, synthetic:						
Australia	17,351	2,103	23,546	3,771	72,218	11,799
France[2]	(3)	1	--	--	--	--
India	5,590	750	11,011	1,398	22,134	3,190
Japan	3,601	682	675	142	1,243	278
Taiwan	19	5	356	68	22,471	3,838
Total	26,561	3,541	35,588	[4]5,375	118,066	19,105
Titaniferous iron ore:[5]						
Canada	82,753	2,526	51,640	1,637	153,714	4,880

[1] Adjusted by the Bureau of Mines.

[2] Country of transshipment rather than country of production.

[3] Less than 1/2 unit.

[4] Data do not add to total shown because of independent rounding.

[5] Includes materials consumed for purposes other than production of titanium commodities, principally heavy aggregate and steel furnace flux.

Table 11.—U.S. imports for consumption of titanium pigments

Country	1976 Quantity (short tons)	1976 Value (thousands)	1977 Quantity (short tons)	1977 Value (thousands)	1978 Quantity (short tons)	1978 Value (thousands)	1979 Quantity (short tons)	1979 Value (thousands)
Australia	1,747	$971	2,573	$1,487	2,633	$1,654	6,119	$4,146
Belgium-Luxembourg	6,703	4,503	11,501	8,630	8,936	7,082	2,620	1,893
Canada	11,285	8,539	15,636	12,246	17,242	13,847	19,808	16,948
Finland	4,813	3,247	4,683	3,242	5,110	3,644	5,791	4,533
France	6,064	4,190	5,039	3,543	11,054	7,943	5,564	4,816
Germany, Federal Republic of	20,069	15,857	46,490	34,742	39,973	33,935	34,961	32,025
India	394	180	463	275	451	250	80	46
Italy	--	--	583	338	650	430	688	496
Japan	3,641	3,606	3,085	2,805	3,562	2,926	4,786	4,362
Mexico	--	--	2,241	1,716	38	23	--	--
Netherlands	229	176	843	676	954	680	20	17
Norway	1,786	1,273	3,614	2,726	1,920	1,467	2,395	1,970
South Africa, Republic of	--	--	--	--	--	--	509	351
Spain	120	65	1,264	902	3,060	2,025	9,830	7,283
Taiwan	--	--	298	240	--	--	--	--
United Kingdom	11,941	7,707	16,182	10,861	21,467	14,362	11,348	8,781
Yugoslavia	--	--	287	255	656	466	461	416
Others	25	28	28	27	2	5	148	127
Total[1]	68,816	50,341	114,810	84,712	117,708	90,741	104,968	88,210

[1] Data may not add to totals shown because of independent rounding.

Table 12.—U.S. imports for consumption of titanium metal

Class and country	1976 Quantity (short tons)	1976 Value (thousands)	1977 Quantity (short tons)	1977 Value (thousands)	1978 Quantity (short tons)	1978 Value (thousands)	1979 Quantity (short tons)	1979 Value (thousands)
Unwrought: Sponge								
China, Mainland	--	--	--	--	--	--	99	$1,533
Japan	1,360	$5,560	1,673	$6,487	756	$3,181	2,058	10,777
U.S.S.R.	256	812	469	1,581	604	2,393	330	2,260
United Kingdom	162	605	245	908	116	514	1	10
Total	1,778	6,977	2,387	8,976	1,476	6,088	2,488	14,580
Ingot and billet:								
Canada	--	--	--	--	24	295	2	49
France	--	--	--	--	--	--	2	38
Germany, Federal Republic of	--	--	--	--	1	6	(1)	(1)
Japan	--	--	--	--	6	75	13	154
U.S.S.R.	--	--	--	--	500	2,131	313	2,473
United Kingdom	--	--	--	--	30	173	8	140
Other	--	--	--	--	--	--	(1)	5
Total[2]	--	--	--	--	561	2,681	338	2,859
Waste and scrap:								
Austria	--	--	--	--	174	448	59	286
Canada	219	291	190	393	299	587	332	1,319
Germany, Federal Republic of	153	317	798	700	393	1,391	321	1,706
Japan	299	554	200	679	105	359	469	2,706
South Africa, Republic of	--	--	--	--	--	--	170	1,762
Sweden	--	--	--	--	44	112	425	1,322
Switzerland	--	--	2	6	192	354	59	264
U.S.S.R.	486	477	1,852	2,202	[3]1,863	[3]3,012	3,313	8,422
United Kingdom	421	823	1,276	2,195	556	1,522	726	3,552
Other	282	312	172	391	164	353	266	927
Total[2]	1,860	2,774	4,494	6,575	3,789	8,139	6,140	22,267
Wrought titanium:								
Canada	135	1,236	64	692	531	3,745	470	3,799
Germany, Federal Republic of	2	28	(1)	7	16	240	29	434
Japan	160	1,408	219	1,704	556	4,663	393	5,081
United Kingdom	21	114	60	261	13	169	28	312
Other	6	153	11	294	10	226	22	518
Total[2]	323	2,939	354	2,958	1,125	9,044	942	10,144

[1] Less than 1/2 unit.
[2] Data may not add to totals shown because of independent rounding.
[3] Includes 55 tons of a metal-slag mixture.

WORLD REVIEW

Australia.—Australia continued to dominate world supplies of titanium concentrates, despite increasing production of high-TiO_2 slag and rutile from the Republic of South Africa, and new production of rutile from Sierra Leone. Australian exports of ilmenite in 1978 and 1979 went mainly to the United Kingdom, the United States, France, Japan, Brazil, and Yugoslavia; rutile was exported mostly to the United States, the United Kingdom, Japan, the Netherlands, and the Federal Republic of Germany.

The world supply of rutile tightened in 1978 and 1979 as production levels at Richards Bay and Sierra Leone increased more slowly than anticipated and production was cut back at several synthetic rutile plants, leading to considerably higher prices for Australian rutile than in 1977.

Some consolidation and merging of sand mining companies took place in 1978-79. The only large-scale operators on the east coast in mid-1979 were Associated Minerals Consolidated Ltd., Mineral Deposits, Ltd., and Rutile and Zircon Mines (Newcastle) Ltd.; and on the west coast, Associated Minerals Consolidated, Westralian Sands, Ltd., Cable Sands Pty. Ltd., Allied Eneabba Pty. Ltd., and Jennings Mining Ltd.[16] In April 1979, it was reported that Du Pont would become a majority shareholder in Allied Eneabba,[17] and in September 1979 Consolidated Gold Fields Australia Ltd. and

Table 13.—Titanium: World production of concentrates (ilmenite, leucoxene, rutile, and titaniferous slag), by country

(Short tons)

Concentrate type and country	1976	1977	1978[p]	1979[e]
Ilmenite and leucoxene:[1]				
Australia:				
Ilmenite	[r]1,057,339	1,139,081	1,383,392	[2]1,258,646
Leucoxene	[r]13,595	11,706	17,752	22,000
Brazil	16,110	14,625	22,131	20,000
Finland	135,143	137,458	145,396	145,000
India	[r] [e]90,000	[3]151,402	[e] [3]165,000	165,000
Malaysia[4]	198,410	169,388	205,929	206,000
Norway	845,101	913,267	845,461	[2]903,576
Portugal	405	252	165	200
Sri Lanka	61,524	37,580	36,421	39,000
U.S.S.R.[e]	420,000	440,000	450,000	450,000
United States[5]	652,404	638,508	589,751	[2]639,292
Total	[r]3,490,031	3,653,264	3,861,397	3,848,714
Rutile:				
Australia	429,625	358,561	283,376	[2]305,773
Brazil	56	141	402	400
India	[r] [e]4,000	[4]6,053	[e] [4]5,500	10,000
Sierra Leone[e]	--	--	--	11,000
South Africa, Republic of[e]	--	5,000	20,000	46,000
Sri Lanka	[r]1,145	1,078	12,673	15,000
U.S.S.R.[e]	[r]10,000	10,000	10,000	10,000
United States	W	W	W	W
Total[6]	[r]444,826	380,833	331,951	398,173
Titaniferous slag:				
Canada[7]	[r]897,350	763,160	937,000	[2]525,840
Japan[7]	3,843	1,354	193	200
South Africa, Republic of[e] [8]	--	--	100,000	330,000
Total	901,193	764,514	1,037,193	856,040

[e]Estimate. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.

[1] Ilmenite is also produced in Canada and in the Republic of South Africa but this output is not included here because it is almost entirely used in production of slag. (See below under titaniferous slag.)

[2] Reported figure.

[3] Data are for fiscal year beginning April 1 of year stated.

[4] Exports.

[5] Includes a mixed product containing ilmenite, leucoxene, and rutile.

[6] Except for U.S. data.

[7] Contains 70% to 72% TiO_2.

[8] Contains 85% TiO_2.

Associated Minerals Consolidated, Ltd. (AMC) announced that they had agreed to purchase Jennings Industries mineral sands operations at Eneabba and Geraldton.[18]

AMC announced that it will expand the capacity of its synthetic rutile plant at Capel to 66,000 tons per year. The company reportedly planned to eventually increase its total synthetic rutile capacity to 132,000 tons per year.

Murphyores Holdings Ltd. was reportedly planning a new $20 million operation near Gladstone in Queensland to produce about 50,000 tons of rutile and zircon, and 140,000 tons of ilmenite per year. Murphyores was also reported in the Australian press to be exerting pressure on the Federal Government to reverse its controversial decision to stop sand mining on Fraser Island.[19]

NL Industries, Inc., late in 1979 sold its subsidiary, Titanium Alloy Manufacturing Co. Pty. Ltd. (Tamco), to Utah Mining Australia, Ltd. Tamco's principal assets included an 85% interest in Mineral Deposits, Ltd., a producer of rutile and zircon concentrates and a manufacturer of mineral processing systems.

In early 1978, Dillingham Corp. announced its withdrawal from mineral sand mining in Australia, stating that the New South Wales Government's action in banning future mining in areas designated as National Parks, combined with the Federal Government's action on Fraser Island at the end of 1976, made it impossible for Dillingham to continue sand mining in Australia.

Canada.—Production of Sorelslag in 1979 by QIT-Fer et Titane, Inc. was only 56% of 1978 output because of a 4-month strike at the company's mine and smelter.

Syncrude Canada Ltd. extracts a total of about 91 million short tons of tar sands annually from which it is estimated that 104,000 tons per year of titanium minerals will be produced. The titanium minerals consist mainly of altered ilmenite believed to be suitable for chloride process TiO_2 manufacture, or for production of synthetic rutile.[30]

China, Mainland.—Titanium sponge metal was exported to the United States for the first time during the last quarter of 1979. China is reported to have several small titanium sponge plants, with total annual capacity in the range of 1,000 to 2,000 tons, using titanium slag made from ilmenite as the main raw material for titanium tetrachloride manufacture. China also was said to be rich in rutile deposits, which occur mainly in Szechwan Province.[31] Current output of titanium dioxide pigment is thought to be about 15,000 to 20,000 tons per year from plants in Peking and Shanghai.

European Economic Community (EEC).—An EEC directive adopted in February 1978 made each country responsible for monitoring its own waste disposal sites and for developing plans to reduce pollution. In mid-1979, exceptions were denied to United Kingdom and Federal Republic of Germany TiO_2 producers, who had applied for exemptions from the directive on the grounds that the conditions pertaining to their disposal situations did not constitute a pollution threat.

There have repeatedly been reports of plans by West European firms to build a 5,000-ton-per-year titanium sponge plant, possibly as a joint venture, to produce material for the EEC market. The companies mentioned in these reports include Pechiney Ugine Kuhlmann Corp., Thyssen AG, Fried. Krupp Huettenwerke AG, and Metallgesellschaft AG.

United Kingdom.—The National Enterprise Board (NEB) announced in late 1979 that it will go ahead with initial plans to construct a new $55 million titanium sponge plant in Shotton, North Wales, in cooperation with state-owned Rolls-Royce Ltd. and IMI Ltd. The new plant will have a capacity of 5,500 tons per year, and will replace the Imperial Chemical Industries Ltd. Teeside facility, which was scheduled to be closed in 1982. The NEB indicated it would seek to transfer its financial participation to the private sector and said it had already received inquiries from a number of interested companies.

India.—A 24,000-ton-per-year chloride process TiO_2 pigment plant was being built by Kerala Minerals and Metal Ltd. (KMML) at Kojlthotham near Quilon, Kerala State. KMML also planned to build a Benilite process synthetic rutile plant. Initial production from a new mineral sands separation plant to be built near the pigment plant was to be about 100,000 tons per year by 1981-82. KMML has been supplying ilmenite to Travancore Titanium Products Ltd.'s sulfate process TiO_2 plant at Quilon. Reserves of the Quilon district were reported to be 39 million tons of ilmenite.

The Orissa Sands Complex Project near Chatrapur, Orissa, was under development, and was expected to produce 220,000 tons of ilmenite in its first phase, possibly by late 1981. A 110,000-ton-per-year synthetic rutile plant was also planned, followed by a second phase of development involving construction of a TiO_2 pigment plant. Reserves of ilmenite in the Chatrapur area were said to be about 250 million tons.[32]

Japan.—In response to the very strong demand for titanium, both Japanese sponge producers expanded production capacity by yearend 1979, as follows: Osaka Titanium Co. Ltd., from 6,600 tons per year to 10,600 tons per year; and Toho Titanium Co. Ltd., from 6,000 tons per year to 7,300 tons per year. It was also planned that in 1980 Osaka would increase capacity further to 12,000 tons per year, and that Toho would raise its capacity to 9,300 tons per year. In addition, the idle sodium reduction (Hunter process) sponge plant of Metal Industry, Ltd., subsidiary of Nippon Soda Company, was to be activated in 1980, with a capacity of 2,400 tons per year, bringing Japan's total annual sponge capacity to 23,700 tons by late 1980, compared with 17,900 tons in 1979, and 12,600 tons in 1978. Japanese production of titanium sponge in 1977, 1978, and 1979 was 7,049 tons, 10,115 tons, and 14,442 tons, respectively, and production in 1980 was expected to be about 20,000 tons.

Sierra Leone.—Sierra Rutile Ltd., owned 85% by Bethlehem Steel Corp. subsidiaries and 15% by Nord Resources Corp., began mining rutile in Sierra Leone from the Mogbwemo deposit about 80 miles southeast of Freetown. Sierra Rutile produced somewhat less than its anticipated 35,000 tons in 1979, but expected to be operating close to capacity production of 110,000 tons per year in 1980. Proven ore reserves are reportedly sufficient for 20 years of production.[33]

South Africa, Republic of—Production of high-titanium slag (85% TiO_2) and rutile by Richards Bay Minerals reportedly reached about 75% of nominal capacity in 1979, and is expected to attain full capacity of 440,000 tons of slag, 62,000 tons of rutile, and 127,000 tons of zircon in 1980.

Sri Lanka.—A rutile-zircon plant was put into operation in 1978 by Ceylon Mineral Sands Corp. at Pulmoddai, with annual capacity of about 14,000 tons of rutile and 8,000 tons of zircon. An expansion program was announced in September 1979 to increase total ilmenite capacity from about 100,000 tons per year to 135,000 tons per year.

U.S.S.R.—Production of titanium sponge metal in the U.S.S.R. was estimated at 42,000 tons in 1979, 8% higher than in 1977. One of the factors contributing to the titanium shortage, particularly in Western Europe, was the much lower volume of titanium sponge exports by the U.S.S.R. in 1978-1979. Possible reasons cited for the lower exports were increased Soviet use in industry and accelerated commercial and military aircraft programs. There were also reports that the Soviet Union has built and tested a titanium-hulled nuclear-powered submarine;[24] such vessels, if the hulls were made entirely of titanium, would probably each require several thousand tons of titanium mill products.

TECHNOLOGY

Bureau of Mines technical publications related to titanium include reports on the design and construction of an apparatus to provide a direct measure of the electron-to-atom transfer ratio in molten salts, such as in the $NaCl\text{-}TiCl_2\text{-}TiCl_3$ system;[25] a study of hot-rolling metals in vacuum;[26] recovery of TiO_2 from slags prepared by soda-smelting ilmenite;[27] corrosion studies in high-temperature, hypersaline geothermal brines;[28] recovery of byproduct heavy minerals from sand and gravel, placer gold, and industrial mineral operations;[29] electric furnace smelting and refining of prereduced titaniferous materials;[30] static casting of small titanium and zirconium shapes;[31] electrodeposition of erosion-resistant titanium diboride coatings;[32] and a process patent for upgrading titanium-bearing materials, including ilmenite, with sulfur trioxide.[33] In a particularly important aspect of this patent, high-TiO_2 slag from the smelting of ilmenite is reacted with sulfur trioxide gas, whereby the calcium and magnesium oxide impurities are converted to double sulfates which can then be leached out of the slag with water. Bureau work was also being carried out on recovery of rutile from porphyry copper mill tailings.

A paper on arc furnace smelting of Western Australian beach sand ilmenite described the preparation of slag containing typically 89.6% TiO_2 equivalent with only 0.09% MgO + CaO, which was claimed, on the basis of chemical composition, to be suitable for manufacture of TiO_2 pigment by either the sulfate or the chloride process.[34] Also published in 1978 were comprehensive articles on the Titania A/S ilmenite mining operation in Norway,[35] and on Western Titanium's Hockin process for making synthetic rutile.[36]

Work directed toward cutting the cost of titanium by developing improved processes for forming titanium was continued. There are three main types of technologies which are being exploited for this purpose: (1) Casting processes that solidify molten metal to obtain the desired shape;[37] (2) processes that consolidate metal powder to the desired shape, such as hot isostatic pressing;[38] and (3) processes that deform wrought metal to the desired shape, such as hot die forging and superplastic forming/diffusion bonding.[39] A critical factor in the successful use of powder consolidation processes was the development of a method for making uncontaminated alloyed titanium powder.[40]

New titanium alloys were also being developed. In 1978, RMI Co. announced a new, commercially pure titanium metal product containing only 0.05% Fe compared with 0.16% Fe in conventional unalloyed titanium. This new grade of titanium was said to have improved corrosion resistance in industrial applications, and was expected to be used mainly in the chemical, paper and pulp, power, marine, food, and pharmaceutical industries. A new alloy containing 10% vanadium, 2% iron, and 3% aluminum, developed by TIMET, was being considered by Boeing Commercial Airplane Co. for use on its new 767 airliners. This trans-beta alloy has better strength-weight properties and can be forged at lower temperatures than other alloys currently used.[41]

Alloys based on the titanium aluminides (Ti_3Al and TiAl) reportedly have a high potential as replacements for nickel- and cobalt-base superalloys in jet engines.[42]

Westinghouse Electric Corp. announced that it received a contract from the Electric Power Research Institute to build the world's first super-conducting generator which will utilize conductors made of titanium-columbium alloy.[43]

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[1] Physical scientist, Nonferrous Metals Section.

[2] Statistical assistant, Nonferrous Metals Section.

[3] Weight units used in this chapter are short tons unless specified otherwise.

[4] Cates, B. Titanium Dioxide From Belgium, France, the United Kingdom, and the Federal Republic of Germany. U.S. Internat. Trade Commission (USITC) Publication 1009, November 1979, 105 pp.

[5] Brown, M. J. Initial Decision in the Matter of E. I. du Pont de Nemours and Co., Docket No. 9108. Federal Trade Commission, Sept. 4, 1979.

[6] American Metal Market. Last Defendants Fined, Sentenced in Titanium Price-Fixing Charges. V. 87, No. 105, May 30, 1979, p. 2.

[7] Mineral Resources of a Portion of the Duluth Complex and Adjacent Rocks in St. Louis and Lake Counties, Northwestern Minnesota. Minn. Dept. of Nat. Res., Div. of Miner., Miner. Exploration Section, Rept. 93, Hibbing, Minn., 1977.

[8] Greensburg, W. Company Loads Train — Waste Shipped to Texas. The Daily Progress, Charlottesville, Va., June 1, 1978. Section B, p. 1.

[9] American Metal Market. U.S. Titanium Must Pay for Waste Removal. V. 88, No. 7, Jan. 11, 1980, p. 5.

[10] American Metal Market. D-H Titanium Organized for Joint Sponge Venture. V. 87, No. 161, Aug. 17, 1979, p. 8.

[11] Turner, D. H. News Release. Howmet Turbine Components Corp., May 8, 1979.

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Tungsten

By Philip T. Stafford[1]

Consumption of tungsten in 1979 was the highest since 1974. Moreover, consumption of tungsten increased each year for 4 consecutive years through 1979. Because increases in domestic production did not keep pace with demand, significant increases in tungsten imports occurred, particularly in 1978 and 1979. Generally, tungsten prices were less volatile in 1978 and 1979 than during the previous several years.

During 1978 and 1979, more than 95% of domestic production came from four mining operations: Two in California, one in Colorado, and one in Nevada. Two new or reopened mines in Nevada with moderate to large capacity were being developed, and at yearend 1979 three ammonium paratungstate (APT) plants were being planned or constructed.

The 16-year deadlock between producing and consuming countries continued, as no agreement was reached during 1978 and 1979 at Geneva conferences on stabilization of the world tungsten market.

Legislation and Government Programs.—General Services Administration (GSA) Office of Stockpile Disposal continued to sell excess stockpiled tungsten concentrate on the basis on monthly sealed bids. During January and February 1978, regular offerings of excess concentrate were made at the rate of 500,000 pounds of contained tungsten per month, of which 375,000 pounds was for domestic use and 125,000 pounds was for export. From March 1978 through yearend 1979, the regular offerings were increased to 600,000 pounds of contained tungsten per month, of which 450,000

Table 1.—Salient tungsten statistics

(Thousand pounds of contained tungsten and thousand dollars)

	1975	1976	1977	1978	1979
United States:					
Concentrate:					
Mine production	5,588	5,830	6,008	6,896	6,643
Mine shipments	5,490	5,869	6,022	6,901	6,646
Value	$29,090	$37,266	$55,073	$56,691	$55,785
Consumption	14,012	16,107	17,100	18,806	21,589
Shipments from Government stocks	2,970	4,004	5,015	5,560	6,363
Exports	1,316	1,729	1,283	1,853	1,929
Imports for consumption	6,570	5,301	6,919	9,138	11,352
Stocks, Dec. 31:					
Producer	531	150	124	87	84
Consumer	1,958	1,002	826	1,424	1,538
Ammonium paratungstate:					
Production	10,282	12,808	14,940	16,062	17,758
Consumption	10,353	15,921	15,744	17,572	18,720
Stocks, Dec. 31: Producer and consumer	1,704	1,438	1,975	1,037	879
Primary products:					
Production	12,634	18,226	19,005	19,028	21,178
Consumption	12,984	16,799	16,905	18,296	20,433
Stocks, Dec. 31:					
Producer	3,976	3,390	3,139	3,349	3,385
Consumer	2,758	2,778	2,581	2,376	2,543
World: Concentrate:					
Production	84,508	[r]90,899	[r]92,948	100,127	101,460
Consumption	73,940	[r]80,408	[r]78,852	86,247	88,109

[r]**Revised.**

pounds was for domestic use and 150,000 pounds was for export. Additionally, during January, February, and March 1978, supplemental offerings of excess concentrate were made on the basis of monthly sealed bids at the rate of 200,000 pounds of contained tungsten per month of which 150,000 pounds was for domestic use and 50,000 pounds was for export. From April 1978 through yearend 1979, the supplemental offerings were increased to 400,000 pounds of contained tungsen per month, of which 300,000 pounds was for domestic use and 100,000 pounds was for export. Concentrate sales in 1978 totaled 4,161,958 pounds of tungsten, of which 2,545,239 pounds was for domestic use and 1,616,719 pounds was for export. In 1979, sales totaled 5,619,354 pounds of tungsten, of which 3,234,888 pounds was for domestic use and 2,384,466 pounds was for export. Actual shipment of excess concentrate from the Government stockpile totaled 5,559,912 and 6,362,517 pounds of contained tungsten in 1978 and 1979, respectively.

Government stockpile goals in effect during 1978-79 remained as revised on October 1, 1976, and reaffirmed on October 7, 1977 (table 2). About 31.9 million pounds of excess tungsten in concentrate were retained to offset shortfalls in the Government stockpile goals of ferrotungsten, tungsten metal powder, and tungsten carbide.

Table 2.—U.S. Government tungsten stockpile material inventories and goals

(Thousand pounds of contained tungsten)

Material	Goals[1]	Inventory by program, Dec. 31, 1979			
		National stockpile	DPA[2] inventory	Supplemental	Total[3]
Tungsten concentrate:					
Stockpile grade	8,823	55,292	999	3,196	59,487
Nonstockpile grade	--	30,928	359	1,043	32,330
Total	8,823	86,219	1,358	4,239	91,817
Ferrotungsten:					
Stockpile grade	17,769	841	--	--	841
Nonstockpile grade	--	1,185	--	--	1,185
Total[3]	17,769	2,025	--	--	2,025
Tungsten metal powder:					
Stockpile grade	3,290	1,567	--	--	1,567
Nonstockpile grade	--	332	--	--	332
Total	3,290	1,899	--	--	1,899
Tungsten carbide powder:					
Stockpile grade	12,845	842	--	1,080	1,922
Nonstockpile grade	--	112	--	--	112
Total[3]	12,845	953	--	1,080	2,033

[1] Goals established Oct. 1, 1976 and reaffirmed in 1977.
[2] Defense Production Act (DPA).
[3] Data may not add to totals shown because of independent rounding.

DOMESTIC PRODUCTION

Domestic mine production and shipments of tungsten in concentrate in 1978 increased 15% over those of 1977, but each decreased 4% in 1979 from those in 1978. Concentrate production and shipments were reported in Alaska and 7 Western States from 68 mines in 1978 and from 50 mines in 1979. However, only three mines operated continuously throughout 1978 and 1979: The Pine Creek mine and mill of the Metals Division, Union Carbide Corp. (UCC), located northwest of Bishop, Calif., in Inyo County; the Climax mine and mill of Climax Molybdenum Co., a division of AMAX Inc., at Climax, Colo., in Lake County; and the Emerson mine and mill of the Metals Division, UCC, at Tempiute, Nev., in Lincoln County. The principal metal mined and concentrated at Pine Creek continued to be tungsten, with minor amounts of byproduct copper, gold, molybdenum, and silver. UCC processed the Pine Creek ore directly into APT, an intermediate tungsten product suitable for conversion to tungsten metal powder.

Scheelite ore was processed at Tempiute to a low-grade tungsten concentrate and shipped to UCC's Pine Creek facility, where it was converted to APT.

The Strawberry mine and mill of Teledyne Tungsten, near North Fork Calif., in Madera Co. began production of tungsten concentrate at a full-capacity rate in mid-1978 and operated continuously until mid-December, when it was closed for the 1978-79 winter. The mine was again in full production from mid-spring through mid-December 1979.

The principal metal mined and processed at Climax was molybdenum. Concentrates of tungsten, tin, and pyrite were recovered as byproducts.

Additionally, intermittent tungsten concentrate production and shipments were reported from Southeastern and Yukon River (1978 only) Regions, Alaska; Pima, Santa Cruz (1979), and Yuma (1978) Counties, Ariz; Fresno, Inyo, Kern, Los Angeles, Mono, San Bernadino, San Diego (1979), and Tulare (1979) Counties, Calif.; Deer Lodge and Jefferson (1978) Counties, Mont.; Churchill, Clark (1978), Elko, Esmeralda (1979), Lincoln, Mineral (1978), Nye, Pershing, and White Pine Counties, Nev.; Box Elder, Davis, and Tooele Counties, Utah; and Stevens County, Wash.

In the latter part of 1979, National Resources Development Inc. began development of the idle Nevada Scheelite mine in northern Mineral County, Nev., about 45 miles southeast of Fallon. Planned concentrate production beginning in early 1980 should add significantly to the U.S. total. The mine last produced in the late 1960's. Late in 1979, Utah International Inc., a subsidiary of General Electric Co., began development of the Springer mine, mill, and APT plant in the vicinity of the abandoned Sutton mines near Imlay in Pershing County, Nev. In early 1982, the complex is expected to begin production of APT at the annual rate of 1.6 million pounds of contained tungsten. Last production from the property was in 1958. The Tungsten Queen mine and mill of Ranchers Exploration & Development Corp., near Townsville, N.C., in Vance County, remained closed and on standby status throughout the year.

AMAX Inc. in late 1979 announced plans for construction of an APT plant at its Fort Madison, Iowa, molybdenum conversion facility. Processing of low-grade scheelite concentrate, primarily from Canada, is scheduled to begin in fall 1981. In mid-1979, Anschutz Mining Corp. purchased an idle NL Industries, Inc., plant in Laredo, Tex., which they plan to convert to an APT plant to begin production in early 1981. The plant last produced synthetic scheelite in 1974 from Guatemalan low-grade concentrate.

Table 3.—Tungsten concentrate shipped from mines in the United States

Year	Quantity			Reported value, f.o.b. mine[1]		
	Short tons 60% WO_3 basis[2]	Short ton units WO_3[3]	Tungsten content (thousand pounds)	Total (thousands)	Average per unit of WO_3	Average per pound of tungsten
1975	5,769	346,112	5,490	$29,090	$84.05	$5.30
1976	6,168	370,069	5,869	37,266	100.70	6.35
1977	6,331	379,729	6,022	55,073	145.03	9.15
1978	7,252	435,117	6,901	56,691	130.29	8.22
1979	6,984	419,040	6,646	55,785	133.13	8.27

[1] Values apply to finished concentrate and are in some instances f.o.b. custom mill.

[2] A short ton of 60% tungsten trioxide (WO_3) contains 951.6 pounds of tungsten.

[3] A short ton unit equals 20 pounds of tungsten trioxide (WO_3) and contains 15.86 pounds of tungsten.

Table 4.—Major producers of tungsten concentrate and principal tungsten processors in 1978-79

Company	Location of mine, mill, or processing plant
Producers of tungsten concentrate:	
Climax Molybdenum Co., a division of AMAX Inc	Climax, Colo.
Teledyne Tungsten	North Fork, Calif.
Union Carbide Corp., Metals Div.[1]	Bishop, Calif.; Tempiute, Nev.
Processors of tungsten:	
Adamas Carbide Corp	Kenilworth, N.J.
Fansteel Inc	North Chicago, Ill.
General Electric Co	Euclid, Ohio; Detroit, Mich.
GTE Sylvania Inc., a subsidiary of General Telephone & Electronics Corp.	Towanda, Pa.
Kennametal Inc	Latrobe, Pa.; Fallon, Nev.
Li Tungsten Corp	Glen Cove, N.Y.
Teledyne Firth Stirling	McKeesport, Pa.
Teledyne Wah Chang Huntsville	Huntsville, Ala.
Union Carbide Corp., Metals Div	Niagara Falls, N.Y.
Westinghouse Electric Corp	Bloomfield, N.J.

[1] At its Pine Creek mine and mill in California, UCC processes ore "straight through" to APT.

CONSUMPTION AND USES

Significant increases in tungsten consumption in primary products occurred for four consecutive years through 1979, and consumption in 1979 was the largest in quantity since 1974. The major end use in 1978 and 1979 continued to be in cutting and wear-resistant materials. In both years, this end use, primarily as tungsten carbide, accounted for 63% of total reported consumption. Other end uses were mill products (1978, 15%; 1979, 16%), specialty steels (both years, 10%), hard-facing rods and materials (1978, 5%; 1979, 3%), superalloys (both years, 3%), and chemicals (both years, 2%).

Consumption in 1978 and 1979 of major intermediate tungsten products used to make end-use items was distributed as follows: Tungsten carbide (1978, 48%; 1979, 51%), tungsten metal powder (1978, 33%; 1979, 31%), and ferrotungsten (1978, 5%; 1979, 4%).

Table 5.—Production, disposition, and stocks of tungsten products in the United States

(Thousand pounds of contained tungsten)

	Hydrogen and carbon-reduced metal powder	Tungsten carbide powder		Chemicals	Other[1]	Total[2]
		Made from metal powder	Crushed and crystal-line			
1978						
Gross production during year	16,548	10,975	1,954	6,914	441	36,832
Used to make other products listed here	11,138	337	281	6,049	--	17,805
Net production	5,410	10,639	1,673	865	441	19,028
Disposition:						
To other processors	295	853	477	463	324	1,912
To end-use consumers	7,334	8,847	304	529	218	17,233
To make products not listed in this table	1,471	1,676	1,348	11	([3])	4,506
Producer stocks, Dec. 31	1,776	641	671	225	36	3,349
1979						
Gross production during year	18,426	12,044	2,507	7,203	328	40,508
Used to make other products listed here	12,390	256	282	6,402	--	19,330
Net production	6,036	11,788	2,225	801	328	21,178
Disposition:						
To other processors	266	3,215	518	223	143	4,365
To end-use consumers	8,956	7,223	428	656	163	17,426
To make products not listed in this table	1,592	1,949	1,823	9	--	5,373
Producer stocks, Dec. 31	1,746	674	716	191	58	3,385

[1] Includes ferrotungsten, scheelite (produced from scrap), nickel-tungsten, and self-reducing oxide pellets.
[2] Data may not add to totals shown because of independent rounding.
[3] Less than 1/2 unit.

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Table 6.—Consumption and stocks of tungsten products in the United States, by end use

(Thousand pounds of contained tungsten)

End use	Ferro-tungsten[1]	Tungsten metal powder[2]	Tungsten carbide powder	Other tungsten materials[3]	Total
1978					
Steel:					
Stainless and heat-resisting	111	W	--	125	236
Alloy	108	W	--	44	152
Tool	514	--	--	871	1,385
Cast irons	1	--	--	--	1
Superalloys	27	198	W	416	641
Alloys (excludes steels and superalloys):					
Cutting and wear-resistant materials	--	2,661	8,211	678	11,550
Other alloys[4]	71	379	327	99	876
Mill products made from metal powder	--	2,725	W	--	2,725
Chemical and ceramic uses	--	--	W	393	393
Miscellaneous and unspecified	1	9	327	--	337
Total	833	5,972	8,865	2,626	18,296
Consumer stocks, Dec. 31	280	172	1,412	512	2,376
1979					
Steel:					
Stainless and heat-resisting	127	--	--	178	305
Alloy	134	--	--	39	173
Tool	445	W	--	1,099	1,554
Cast irons	--	--	--	--	--
Superalloys	51	71	W	474	596
Alloys (excludes steels and superalloys):					
Cutting and wear-resistant materials	--	2,720	9,804	445	12,969
Other alloys[4]	14	234	313	85	646
Mill products made from metal powder	--	3,337	W	11	3,348
Chemical and ceramic uses	--	--	--	506	506
Miscellaneous and unspecified	3	3	330	--	336
Total	784	6,365	10,447	2,837	20,433
Consumer stocks, Dec. 31	150	166	1,568	659	2,543

W Withheld to avoid disclosing company proprietary data, included in "Miscellaneous and unspecified."

[1] Includes melting base self-reducing tungsten.

[2] Includes both carbon-reduced and hydrogen-reduced tungsten metal powder.

[3] Includes tungsten chemicals, natural and synthetic scheelite, tungsten scrap, and other.

[4] Includes welding and hard-facing rods and materials and nonferrous alloys.

PRICES

In 1978, the average value of tungsten concentrate shipped from domestic mines and mills, as reported to the Bureau of Mines, decreased 10% to $130.29 per short ton unit of WO_3, compared with the 1977 value, but during 1979, it increased 2% to $133.13, compared with the 1978 value. GSA sold excess tungsten concentrate on the basis of monthly sealed bids in the following ranges of prices, ex-duty, per short ton unit: 1978, $114.91 to $133.78 for domestic uses and $115.03 to $132.27 for export; 1979, $108.58 to $136.99 for domestic use and $144.81 to $138.30 for export.

The European prices of tungsten concentrate as reported in *Metal Bulletin* (London), the U.S. spot quotations, and the International Tungsten Indicator prices showed similar trends, and monthly and annual averages, during 1978 and 1979. Generally, concentrate prices were less volatile than during the previous several years.

The reported price of APT delivered to large volume contract customers was $180 per short ton unit at the beginning of 1978. It fell to $174 on February 1, $165 on March 1, and $155 on June 1. The prices rose to $165 per short ton unit on December 1, 1978, fell to $155 on February 1, 1979, and rose to $165 on June 1. It remained at that level for the remainder of 1979.

The price of hydrogen-reduced tungsten metal powder (99.9% purity), f.o.b. shipping point, as quoted in *Metals Week*, remained stable throughout 1978 and 1979 in the price range of $13.90 to $15.50 per pound. Within these ranges, the price was primarily dependent upon the tungsten powder particle size.

The quoted price of UCAR ferrotungsten, a proprietary high-purity ferroalloy containing 90% tungsten, decreased from $12.10 per pound at the beginning of 1978 to $11.70 on February 1, $11.10 on March 1, and $10.50 on May 1. The price rose to

Table 7.—Monthly price quotations of tungsten concentrate in 1978-79

Month	Metal Bulletin (London), wolframite, European market, 65% WO_3 basis[1]					Metals Week, U.S. spot quotations, dollars per short ton unit WO_3 65% basis, c.i.f. U.S. ports[2]			Tungsten Users' Index (Jan.-May 1978), International Tungsten Indicator (June 1978- Dec. 1979), weighted average price, 60%-79% WO_3	
	Dollars per metric ton unit WO_3		Equivalent prices, dollars per short ton unit of WO_3							
	Low	High	Low	High	Average	Low	High	Average	Dollars per metric ton unit	Dollars per short ton unit
1978										
January	153.00	173.00	138.80	156.94	150.14	141.00	150.00	144.88	162.23	147.18
February	139.50	163.00	126.55	147.87	135.57	126.50	137.00	134.00	151.71	137.63
March	142.00	154.00	128.82	139.71	135.96	127.00	140.00	133.25	150.30	136.35
April	137.00	154.00	124.28	139.71	132.56	123.00	134.00	128.38	143.73	130.39
May	131.00	145.00	118.84	131.54	124.96	124.00	126.00	125.00	141.31	128.19
June	127.00	137.00	115.21	124.28	120.35	115.00	119.25	117.08	137.45	124.69
July	129.00	139.00	117.08	126.10	121.11	117.00	119.75	118.19	136.77	124.08
August	131.00	142.50	118.84	129.27	124.34	118.50	128.00	121.69	136.76	124.07
September	140.00	146.00	127.01	132.45	129.58	126.00	132.00	129.65	142.14	128.95
October	141.50	150.00	128.37	136.08	131.37	130.00	132.00	131.09	142.53	129.30
November	139.00	150.00	126.10	136.08	131.83	125.00	132.00	130.47	142.26	129.06
December	134.50	148.00	122.02	134.26	127.35	120.50	132.00	126.25	143.90	130.54
1979										
January	120.00	138.00	108.86	125.19	117.93	115.50	128.50	121.25	138.33	125.49
February	115.00	146.00	104.33	132.45	116.29	107.50	127.50	115.00	131.24	119.06
March	134.50	149.00	122.02	135.17	128.54	130.00	136.50	132.20	137.42	124.67
April	131.00	140.00	118.84	127.01	122.66	120.00	133.00	126.88	135.55	122.97
May	136.00	144.50	123.38	131.09	127.20	123.00	131.00	127.13	137.28	124.54
June	142.00	151.00	128.82	136.98	133.43	125.00	135.25	131.05	141.03	127.94
July	134.00	148.00	121.56	134.26	127.71	122.50	135.25	129.56	142.51	129.28
August	135.00	149.00	122.47	135.17	129.61	123.50	140.50	131.48	140.71	127.65
September	142.50	149.00	129.27	135.17	132.82	127.00	140.50	134.66	142.42	129.20
October	140.00	146.00	127.01	132.45	129.58	127.00	134.50	130.88	143.09	129.81
November	132.00	144.00	119.75	130.63	125.85	122.75	134.50	127.40	140.58	127.53
December	128.00	136.00	116.12	123.38	119.72	118.00	122.50	120.25	137.85	125.06

[1] Low and high prices as reported semiweekly. Monthly equivalent averages are arithmetic average of semiweekly equivalent low and high prices. The equivalent average price per short ton unit of WO_3, which is an average of all semiweekly low and high prices, excluding duty, was $130.43 for 1978 and $125.95 for 1979.

[2] Low and high prices as reported weekly. Monthly averages are arithmetic average of weekly low and high prices. The average price per short ton unit of WO_3, which is an average of all weekly low and high prices, excluding duty, was $128.19 for 1978 and $127.31 for 1979.

[3] Weighted average price per short ton unit of WO_3, excluding duty, was $129.67 for 1978 and $126.10 for 1979.

$11.10 per pound on December 1, 1978, fell to $10.50 on February 1, 1979, rose to $11.25 on May 1, and rose again to $11.55 on June 1. It remained at that level for the remainder of 1979.

FOREIGN TRADE

Effective March 1, 1979, Executive Order 12124 amended the Generalized System of Preferences so that ore and concentrate, ferrotungsten and ferrosilicon tungsten, and waste and scrap containing by weight not over 50% tungsten from designated beneficiary developing countries could be imported into the United States duty free.

The Tokyo Round of multilateral trade negotiations was completed in 1979. Tariff rates for tungsten-containing forms from the beginning (Jan. 1, 1980) to the end (Jan. 1, 1987) of the staging period, as published in the Tariff Schedules of the United States (1980), are shown in table 17.

Table 8.—U.S. exports of tungsten ore and concentrate, by country

(Thousand pounds and thousand dollars)

Country	1978		1979	
	Tungsten content	Value	Tungsten content	Value
Austria	52	369	374	2,318
Brazil	1	7	60	404
France	53	355	--	--
Germany, Federal Republic of	484	3,266	582	4,743
India	33	196	--	--
Italy	1	2	--	--
Japan	10	97	698	3,760
Mexico	1	1	--	--
Netherlands	370	2,679	136	1,051
Trinidad	1	1	--	--
United Kingdom	845	5,582	84	633
Total	[1]1,853	12,555	1,929	12,909

[1] Data do not add to total shown because of independent rounding.

Table 9.—U.S. exports of ammonium paratungstate, by country

(Thousand pounds and thousand dollars)

	1978			1979		
	Gross weight	Tungsten content[1]	Value	Gross weight	Tungsten content[1]	Value
Australia	(2)	(2)	1	(2)	(2)	1
France	8	6	21	5	4	14
Germany, Federal Republic of	--	--	--	1	1	7
India	(2)	(2)	1	--	--	--
Netherlands	44	31	341	--	--	--
Sweden	56	39	373	--	--	--
United Kingdom	201	142	1,724	(2)	(2)	4
Total[3]	310	219	2,461	7	5	26

[1] Tungsten content estimated by multiplying gross weight by 0.7066.
[2] Less than 1/2 unit.
[3] Data may not add to totals shown because of independent rounding.

Table 10.—U.S. exports of tungsten carbide powder, by country

(Thousand pounds and thousand dollars)

Country	1978		1979	
	Tungsten content	Value	Tungsten content	Value
Argentina	5	64	21	291
Australia	1	10	9	188
Austria	11	99	96	1,096
Belgium-Luxembourg	14	177	30	589
Brazil	19	386	23	461
Canada	762	4,334	364	5,764
Chile	1	8	(1)	4
Denmark	40	251	64	596
Finland	2	18	14	269
France	4	60	65	721
Germany, Federal Republic of	133	1,505	256	3,872
India	2	16	(1)	15
Ireland	28	561	11	210
Israel	51	486	20	341
Italy	66	891	60	1,305
Japan	20	388	61	817
Mexico	94	1,166	122	2,549
Netherlands	31	455	51	850
Peru	8	55	3	38
Singapore	5	86	2	42
South Africa, Republic of	(1)	202	4	64
Spain	(1)	5	2	41
Sweden	51	1,141	18	224
Switzerland	36	484	15	258
Taiwan	--	--	9	259
Trinidad	(1)	2	1	12
United Kingdom	53	843	60	1,257
Venezuela	2	28	2	30
Other	(1)	75	(1)	12
Total[2]	1,453	13,788	1,392	22,096

[1] Less than 1/2 unit.
[2] Data do not add to totals shown because of independent rounding.

Table 11.—U.S. exports of tungsten and tungsten alloy powder, by country

(Thousand pounds and thousand dollars)

Country	1978			1979		
	Gross weight	Tungsten content[1]	Value	Gross weight	Tungsten content[1]	Value
Australia	1	(2)	8	2	1	27
Austria	7	6	86	11	9	128
Belgium-Luxembourg	2	1	24	(2)	(2)	3
Brazil	1	1	12	1	1	23
Canada	72	58	921	57	46	837
Denmark	1	1	6	--	--	--
Finland	29	24	250	8	6	96
France	3	2	38	10	8	97
Germany, Federal Republic of	43	34	706	206	164	4,135
Israel	579	463	6,452	360	288	3,415
Italy	1	1	13	6	5	72
Japan	80	24	363	31	25	405
Mexico	(2)	(2)	4	30	24	403
Singapore	--	--	--	20	16	228
Spain	1	1	15	(2)	(2)	6
Sweden	107	86	1,224	58	47	618
Switzerland	1	1	6	--	--	--
Taiwan	3	3	53	12	10	200
Turkey	--	--	--	8	6	119
United Kingdom	13	10	197	6	5	76
Other	1	1	19	2	1	28
Total[3]	895	716	10,409	827	662	10,907

[1] Tungsten content estimated by multiplying gross weight by 0.80.
[2] Less than 1/2 unit.
[3] Data may not add to totals shown because of independent rounding.

Table 12.—U.S. exports of miscellaneous tungsten-bearing materials

(Thousand pounds and thousand dollars)

Product and country	1978 Gross weight	1978 Value	1979 Gross weight	1979 Value
Tungsten and tungsten alloy wire:				
Brazil	28	1,577	18	1,648
Canada	54	2,321	44	2,640
Italy	7	441	8	704
Mexico	11	1,046	21	2,079
United Kingdom	19	1,556	15	1,480
U.S.S.R	21	774	5	276
Other	62	5,011	47	5,235
Total[1]	201	12,724	162	14,016
Unwrought tungsten and alloy in crude form, waste, and scrap:				
Austria	--	--	87	609
Canada	154	1,323	126	1,150
Germany, Federal Republic of	683	4,235	562	3,886
Israel	80	889	2	22
South Africa, Republic of	--	--	49	552
Sweden	68	565	50	573
United Kingdom	10	63	89	486
Other	116	747	60	467
Total[1]	1,120	7,822	1,025	7,835
Other tungsten metal:				
Austria	([2])	12	52	772
Canada	43	857	61	1,190
Germany, Federal Republic of	115	1,643	167	3,425
Netherlands	61	271	([2])	8
United Kingdom	75	1,699	79	1,973
Other	49	1,564	88	2,536
Total[1]	343	6,046	436	9,904

[1] Data may not add to totals shown because of independent rounding.
[2] Less than 1/2 unit.

Table 13.—U.S. imports for consumption of tungsten ore and concentrate, by country

(Thousand pounds and thousand dollars)

Country	1978 Tungsten content	1978 Value	1979 Tungsten content	1979 Value
Australia	211	1,514	398	2,856
Bolivia	2,012	15,543	2,980	22,511
Brazil	2	22	26	188
Burma	45	356	253	1,802
Canada	3,030	22,509	3,127	23,558
Chile	8	54	4	15
China, Mainland	714	5,832	1,168	9,315
France	392	2,515	251	1,749
Germany, Federal Republic of	46	402	--	--
Hong Kong	18	168	--	--
Korea, Republic of	230	1,877	84	640
Malaysia	136	1,012	61	479
Mexico	850	4,688	607	3,536
Peru	180	1,406	810	6,106
Portugal	--	--	195	1,546
Rwanda	150	1,187	6	46
Singapore	--	--	11	85
South Africa, Republic of	17	26	4	32
Spain	--	--	20	148
Sweden	70	633	15	123
Thailand	840	6,644	1,246	9,278
United Kingdom	34	260	--	--
Zaire	146	1,086	86	648
Total[1]	9,188	67,733	11,352	84,661

[1] Data may not add to totals shown because of independent rounding.

Table 14.—U.S. imports for consumption of ammonium paratungstate, by country

(Thousand pounds and thousand dollars)

Country	1978		1979	
	Tungsten content	Value	Tungsten content	Value
France	--	--	47	450
Germany, Federal Republic of	--	--	8	114
Japan	--	--	16	130
Korea, Republic of	513	5,067	204	1,806
Sweden	--	--	76	755
United Kingdom	--	--	86	892
Total	513	5,067	437	4,176

Table 15.—U.S. imports for consumption of ferrotungsten, by country

(Thousand pounds and thousand dollars)

Country	1978		1979	
	Tungsten content	Value	Tungsten content	Value
Austria	241	2,148	104	928
Brazil	71	623	171	1,575
Canada	8	69	--	--
France	110	1,028	83	767
Germany, Federal Republic of	63	581	25	240
Portugal	2	20	82	752
Sweden	60	544	105	967
United Kingdom	19	192	--	--
Total[1]	575	5,206	570	5,228

[1] Data may not add to totals shown because of independent rounding.

Table 16.—U.S. imports for consumption of miscellaneous tungsten-bearing materials

(Thousand pounds and thousand dollars)

Product and country	1978		1979	
	Tungsten content	Value	Tungsten content	Value
Other metal-bearing materials in chief value of tungsten:				
Korea, Republic of	188	1,556	--	--
Thailand	37	289	14	85
Other	9	62	21	49
Total[1]	234	1,908	34	135
Waste and scrap containing not over 50% tungsten:				
Germany, Federal Republic of	--	--	13	117
Other	1	9	14	50
Total[1]	1	9	26	167
Waste and scrap containing over 50% tungsten:				
Belgium	15	130	22	282
Canada	16	115	22	205
France	41	288	110	1,041
Germany, Federal Republic of	11	111	66	783
Israel	10	72	192	1,644
Japan	19	158	35	358
Mexico	12	88	23	398
Singapore	6	63	23	236
Sweden	9	50	22	35
United Kingdom	--	--	111	1,100
Other	6	31	12	113
Total[1]	145	1,107	639	6,195

See footnotes at end of table.

Table 16.—U.S. imports for consumption of miscellaneous tungsten-bearing materials —Continued

(Thousand pounds and thousand dollars)

Product and country	1978		1979	
	Tungsten content	Value	Tungsten content	Value
Unwrought tungsten, except alloys, in lumps, grains, and powders:				
France	8	131	80	901
Germany, Federal Republic of	267	3,276	13	157
Japan	38	342	15	126
Korea, Republic of	(2)	3	509	5,161
Other	24	233	28	283
Total[1]	332	3,986	646	6,628
Unwrought tungsten, ingots and shot[3]	1	9	6	68
Unwrought tungsten, other:[3]				
Canada	61	345	(2)	5
Japan	(2)	9	11	154
Korea, Republic of	--	--	17	245
Singapore	--	--	11	158
Other	(2)	8	1	11
Total[1]	61	361	40	574
Unwrought tungsten, alloys	2	48	8	156
Wrought tungsten:[3]				
Austria	27	874	17	601
Canada	79	1,050	103	1,121
Japan	6	1,065	14	1,194
Other	6	97	11	343
Total[1]	119	3,086	145	3,260
Calcium tungstate:				
Germany, Federal Republic of	329	2,691	41	1,016
Sweden	40	351	--	--
United Kingdom	--	--	6	13
Total	369	3,042	47	1,029
Tungsten carbide:				
Canada	1	27	32	357
Germany, Federal Republic of	149	2,106	320	4,431
Korea, Republic of	8	96	72	747
Mexico	(2)	5	12	320
Sweden	127	2,108	113	2,436
United Kingdom	31	501	6	45
Other	13	212	2	35
Total[1]	331	5,054	557	8,371
Other tungsten compounds:				
Australia	--	--	25	183
Other	2	29	2	48
Total	2	29	27	231
Mixtures, organic compounds, chief value in tungsten:				
Canada	39	457	8	135
Germany, Federal Republic of	3	53	5	97
United Kingdom	(2)	5	--	--
Total	42	515	13	232

[1] Data may not add to totals shown because of independent rounding.

[2] Less than 1/2 unit.

[3] Estimated from reported gross weight.

Table 17.—U.S. import duties on all forms of tungsten

Tariff classification	Article	Rate of duty effective Jan. 1, 1980	
		Most favored nation (MFN)	Non-MFN
601.54	Tungsten ore	17 cents per pound on tungsten content.	50 cents per pound on tungsten content.
603.45	Other metal-bearing materials in chief value of tungsten.	16 cents per pound on tungsten content and 7.6% ad valorem.	60 cents per pound on tungsten content and 40% ad valorem.
606.48	Ferrotungsten and ferrosilicon tungsten	21 cents per pound on tungsten content and 6% ad valorem.	35% ad valorem.
629.25	Waste and scrap containing by weight not over 50% tungsten.	7.3% ad valorem	50% ad valorem.
629.26	Waste and scrap containing by weight over 50% tungsten.	7.5% ad valorem	Do.
629.28	Unwrought tungsten, except alloys, in lumps, grains, and powders.	21 cents per pound on tungsten content and 12.5% ad valorem.	58% ad valorem.
629.29	Unwrought tungsten, ingots and shot	10.5% ad valorem	50% ad valorem.
629.30	Unwrought tungsten, other	12.5% ad valorem	60% ad valorem.
629.32	Unwrought tungsten, alloys, containing by weight not over 50% tungsten.	6.7% ad valorem	35.5% ad valorem.
629.33	Unwrought tungsten, alloys, containing by weight over 50% tungsten.	12.5% ad valorem	60% ad valorem.
629.35	Wrought tungsten	11.8% ad valorem	Do.
416.40	Tungstic acid	14.4% ad valorem	55% ad valorem.
417.40	Ammonium tungstate	12.9% ad valorem	49.5% ad valorem.
418.30	Calcium tungstate	11.1% ad valorem	43.5% ad valorem.
420.32	Potassium tungstate	23.1% ad valorem	50.5% ad valorem.
421.56	Sodium tungstate	12.4% ad valorem	46.5% ad valorem.
422.40	Tungsten carbide	16 cents per pound on tungsten content and 12.5% ad valorem.	55.5% ad valorem.
422.42	Other tungsten compounds	11.7% ad valorem	45.5% ad valorem.
423.92	Mixtures of two or more inorganic compounds in chief value of tungsten.	do	Do.

WORLD REVIEW

During February 1978, the ad hoc Intergovernmental Group of Experts on Tungsten (IGET) of the Committee on Tungsten (COT) of the United Nations Conference on Trade and Development (UNCTAD) met at Geneva, Switzerland. There was no agreement between producing and consuming countries concerning the stabilization of the world tungsten market, which was the purpose of the meeting. However, detailed studies by IGET of the various areas affecting price and trade of tungsten were forwarded by COT to the Trade and Development Board (TDB) of UNCTAD. In April 1978, the TDB met in Geneva, considered the IGET and COT report, and requested that the Secretary-General of UNCTAD convene a preparatory working group to futher examine and assess proposals for stabilization of the market. In June 1978, the first UNCTAD Preparatory Working Group for Tungsten (PWG) meeting was held in Geneva. The meeting ended in a consensus agreement that a further session be held at some time in the future; the United States did not join in the consensus and Bolivia did not attend the meeting. A meeting of the PWG was held in Geneva during September 1979 in an effort to resolve the 16-year deadlock. No agreement was reached, but the TDB in October 1979 requested COT to review its past work, to determine guidelines for reaching an agreement, and to convene a meeting of the committee no later than March 1980.

Australia.—In early May 1978, Queensland Wolfram Pty., Ltd. (QW), officially opened the new opencut Mt. Carbine mine and mill in northern Queensland near Cairns. The facility was expected to produce concentrate containing 1.7 million pounds of tungsten per year from wolframite and sheelite ore averaging 0.1% WO_3. Because of the extremely low-grade ore, it was necessary to install a method of sorting the ore from the gangue at high speed. During 1978 and 1979, this was done by three photometric ore-sorting machines. QW is 75%-owned by RB Mining Pty. Ltd., an Australian company, and 25%-owned by Sandvik Aktiobolag (of Sweden), A. Johnson & Co. HAB (of Sweden), and Treibacher Chemische Werke AG (of Austria).[3]

Other major production in Australia dur-

Table 18.—Tungsten: World concentrate production, by country

(Thousand pounds of contained tungsten)[1]

Country	1976	1977	1978	1979[e]
North and Central America:				
Canada	[r]3,790	3,994	5,045	[3]5,740
Mexico	[r]414	322	409	440
United States	[r]5,869	6,022	6,901	[3]6,646
South America:				
Argentina	[r]137	154	174	170
Bolivia	[r]7,015	6,515	6,288	[3]5,836
Brazil	[r]2,120	2,672	2,557	3,000
Peru	1,303	1,160	1,283	1,100
Europe:				
Austria	1,193	2,460	2,599	2,600
Czechoslovakia[e]	175	175	175	175
France	[r]1,396	1,440	1,340	1,300
Portugal	[r]2,776	2,216	2,407	[3]2,778
Spain	[r]725	679	602	700
Sweden	428	439	1,279	880
U.S.S.R.[e]	17,600	18,100	18,700	19,000
United Kingdom	[e]22	172	143	50
Africa:				
Burundi	4	[e]4	[e]4	4
Nigeria	([2])	--	--	--
Rhodesia, Southern[e]	[r]130	130	130	130
Rwanda	952	1,252	849	850
South-West Africa, Territory of (Namibia)[e] [4]	[r]310	330	330	360
Uganda[e]	240	240	240	240
Zaire	[r]522	375	326	330
Asia:				
Burma	[r]608	613	1,038	1,550
China, Mainland[e]	19,800	19,800	22,000	22,000
India	51	62	46	50
Japan	[r]1,786	1,693	1,678	1,700
Korea, North[e]	4,740	4,740	4,740	4,740
Korea, Republic of	[r]5,703	5,809	5,734	[3]5,664
Malaysia	141	218	159	150
Thailand	[r]4,519	4,859	7,026	[3]6,230
Turkey	2,046	[e]1,100	15	140
Oceania: Australia	[r]4,384	5,198	5,910	[3]6,907
Total	[r]90,899	92,943	100,127	101,460

[e] Estimate. [r] Revised.

[1] Conversion factors: WO_3 to W, multiply by 0.7931; 60% WO_3 to W, multiply by 0.4758.

[2] Revised to none.

[3] Reported figure.

[4] Production of Brandberg West mine of South Africa Company, Ltd. Data are for calendar years.

ing 1978-79 took place on King Island in Bass Strait from the Bold Head and Dolphin mines of King Island Scheelite Pty., Ltd., and in northeastern Tasmania from the Storeys Creek and Aberfoyle mines, of Aberfoyle Ltd. The latter two mines also produced tin as coproduct.

Canada.—The mine and mill operated by Canada Tungsten Mining Corp. Ltd. (CTMC), at Tungsten, Northwest Territories, accounted for all Canadian production of tungsten in concentrate in 1978 and 1979. Production capacity of the facility was doubled in July 1979 to 1,000 tons of ore per day. Reserves were reported by the company to contain 96 million pounds of tungsten at yearend 1979.[3]

During mid-1978, AMAX Securities, Inc., a wholly owned subsidiary of AMAX Inc., increased its ownership of CTMC from 47% to 65%.[4]

Korea, Republic of.—Tungsten in concentrate produced by Korea Tungsten Mining Co., Ltd. (KTMC), increased 4% to 5.2 million pounds in 1978 and 5% to 5.4 million pounds in 1979 compared with that of 1977 and 1978, respectively, and accounted for approximately 90% of the Republic of Korea production. KTMC produced 4.3 million pounds of ammonium paratungstate in 1978 and 3.2 million pounds in 1979, the entire production of the country.

Portugal.—Production of tungsten concentrate by the major tungsten producer, Beralt Tin & Wolfram (Portugal) SARL (BTWP) at the Panasqueira mine, increased 13% during 1978 to 1.9 million pounds of tungsten and 23% during 1979 to 2.3 million pounds compared with that of 1977 and 1978, respectively. Tin and copper were produced as byproducts. Ore reserves were reported as 35 million pounds of tungsten at

Table 19.—Tungsten: World concentrate consumption, by country[1]

(Thousand pounds of contained tungsten)

Country[2]	1976	1977	1978	1979[e] [3]
Actual consumption:				
Australia	88	88	88	90
Austria	3,505	[r]3,183	5,240	5,000
Canada	639	[r]730	679	700
France	3,139	2,207	3,611	2,800
Japan	5,677	4,667	4,489	4,500
Korea, Republic of	[e] [3]1,600	3,175	3,042	3,000
Mexico	71	130	[e] [3]130	130
Portugal	595	302	388	400
Sweden	3,761	[r]3,746	3,494	3,500
United Kingdom	4,251	[r]3,667	4,383	4,300
United States	16,107	17,100	18,806	21,500
Apparent consumption:[4]				
Argentina	137	[e] [3]130	[e] [3]150	150
Belgium-Luxembourg	401	[r]53	--	--
Brazil[e]	[r]550	[r]550	550	550
China, Mainland[e] [3]	4,740	5,100	5,300	5,500
Czechoslovakia[e] [3]	2,700	[r]2,900	2,900	2,900
German Democratic Republic[e] [3]	600	600	600	600
Germany, Federal Republic of	4,464	2,943	3,585	3,700
Hungary[3]	1,320	1,320	[3]1,320	1,320
India	[r]598	[r]597	[e] [3]600	600
Italy[e]	125	110	130	130
Korea, North[e] [3]	3,500	3,500	3,500	3,500
Netherlands	[r]798	[r]1,111	896	900
Poland	4,231	3,935	4,806	3,600
South Africa, Republic of[e]	550	550	550	550
Spain	168	168	220	300
U.S.S.R.[e] [3]	16,100	16,300	16,700	17,200
Total	[r]80,408	[r]78,852	[r]86,247	[r]88,100

[e] Estimate. [r] Revised.

[1] Source, unless otherwise specified, is the Quarterly Bulletin of the UNCTAD Committee on Tungsten. Tungsten Statistics. V. 14, No. 1, January 1980, 54 pp.

[2] In addition to the countries listed, Bulgaria, Denmark, Finland, Israel, Norway, Romania, Switzerland, and Yugoslavia may consume tungsten concentrate, but consumption levels are not reported and available general information is inadequate to permit formulation of reliable estimates of consumption levels.

[3] Estimated by U.S. Bureau of Mines. (All estimates not so footnoted are reported in the primary source.)

[4] Production plus imports minus exports. For a few countries where data were available, variations in stocks were used in determining consumption.

yearend 1978. BTWP, a Portuguese company, is owned 80.5% by Beralt Tin & Wolfram, Ltd., a United Kingdom company.[5]

In December 1978, the mine, mill, concessions, ferrotungsten plant, and other ancillary assets of the Borralha facility near Venda Nova in northern Portugal, owned by Mines de Borralha S. A., a French company, were acquired by a new Portuguese company, Minas da Borralha SARL, in which BTWP has an 80.5% interest. Production of tungsten in concentrate from the Borrahla mine in 1978 totaled almost 0.3 million pounds and in 1979 more than 0.4 million pounds, all of which was converted to ferrotungsten at the facility. Ore reserves were 4.4 million pounds of tungsten at yearend 1978. Copper and silver were produced as byproducts.[6]

Thailand.—In August and September 1978, an estimated 5,000 miners began illegally mining tungsten ore from a newly discovered deposit at Doi Ngon about 40 kilometers from Phrae. Thai authorties were hesitant to take action, but finally restored order in mid-September. The Government subsequently approved a nine-point proposal of the Ministry of Industry to control mining and protect the concessionaires.

Labor-intensive methods in Thailand have tended to leave behind significant amounts of lower grade tungsten ores. As a result, many mines that still have substantial deposits of low-grade wolframite ore were closed. This caused a drop in the production and export of tungsten ores and concentrates during 1979.

TECHNOLOGY

The Bureau of Mines reported the results of laboratory tests to devise a procedure for recovering a marketable grade of tungsten from the brine of Searles Lake, Calif., in the Mojave Desert 170 miles northeast of Los Angeles. The brine contains only 56 ppm of tungsten. Using ion-exchange resin synthesized by the Bureau chemists, more than 99% of the tungsten was extracted from the brine and 92% of the tungsten was recovered as marketable iron-tungsten concentrate containing 44% tungstic acid.[7] A 5,000-gallon-per-day pilot expansion of the laboratory ion-exchange unit was erected at Searles Lake to provide engineering data for an economic appraisal and possible escalation to enable recovery of nearly 1,100 pounds of tungsten daily from 2.6 million gallons of brine. The Searles Lake brines were estimated to contain 135 million pounds of tungsten.[8]

Photometric ore-sorting machines were perfected in 1978 by R. B. Mining Pty. Ltd. engineers who obtained rights to the basic technology of photometric ore-sorting from Ore Sorters Africa in the Republic of South Africa for use at the Mt. Carbine tungsten mine and mill of Wolfram Pty. Ltd. in northern Queensland, Australia. This is the first time photometric ore-sorting has been used commercially for concentrating tungsten ores.[9]

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[1] Physical Scientist, Section of Ferrous Metals.

[2] Primary Tungsten Association (London). Mt. Carbine Wolframite Mine (R. B. Mining Pty. Ltd.). Quarterly Bull., No. 5, September 1978, pp. 6-8.

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Depleted Uranium

By William S. Kirk[1]

Depleted uranium for nonenergy applications in the United States was a byproduct of enriching natural uranium for nuclear applications by the Department of Energy (DOE). The quantity that was available greatly exceeded current and foreseeable demand. In both 1978 and 1979, depleted uranium metal and depleted UF_6, valued at about $20 million, was shipped by DOE primarily for use in ordnance applications. Containers for spent nuclear reactor residues and other radiation shielding applications, counterweights and ballast for aircraft and ships, and research accounted for the remainder of consumption, which was believed to be 10% to 20% of the total. All data in this chapter are stated in terms of uranium content.

Legislation and Government Programs.—Depleted uranium, though only mildly radioactive, is treated as a source material in the U.S. Code of Federal Regulations and is referred to in section 10 CFR 40.25 and 10 CFR 110.23 As a source material, ownership and use of depleted uranium materials must be licensed by the Nuclear Regulatory Commission or certain State agencies.[2]

The Tokyo Round of negotiations was completed in 1979, resulting in new tariff agreements for minerals, including depleted uranium, with the developed nations of the world. The agreements placed most nations on a most-favored-nation basis with generally lower rates to be phased in, or staged, between January 1, 1980, and January 1, 1987.

DOMESTIC PRODUCTION

DOE was the sole domestic processor of uranium to produce a uranium product that is enriched in the isotope uranium 235 (U_{235}) for nuclear applications. About 4.5 tons of depleted uranium hexafluoride (UF_6) is generated for each ton of commercial power-reactor-grade enriched UF_6 produced. If a more enriched product is required, such as for weapons use, a considerably larger quantity of depleted uranium product is generated for each ton of the enriched product. Depleted uranium is composed almost entirely of uranium 238 (U_{238}) but still contains small percentages of U_{235}.

The DOE generated about 20,000 tons of depleted UF_6 in 1978 and about 21,000 tons during 1979, bringing the total quantity of depleted uranium generated by DOE to over 300,000 tons.

In September 1979, the Army awarded a $3 million contract to Nuclear Metals Inc. (NMI), Concord, Mass., to install equipment that would give NMI the capability to produce 20,000 XM-774 105mm depleted uranium penetrators per month. The capability would be available for use in an emergency mobilization. Early in 1979, NMI acquired the capablilty to reduce depleted uranium tetrafluoride (UF) to the metal.

TNS, a subsidiary of Aerojet Ordnance Co., doubled the floor space devoted to processing depleted uranium, at Jonesboro, Tenn., during 1978 and 1979. In 1979, TNS increased by 33% its capacity to reduce depleted UF_4 to metal and tripled its vacuum melting capacity.

Through the years, DOE has reduced some of the depleted UF_6 to UF_4 to release valuable storage cylinders for other uses and to recover the fluorine. Most of the shipments of depleted uranium for nonenergy applications have been in the form of UF$_4$. In 1978, DOE shipped 2,159 tons of depleted UF$_4$ to the Feed Materials Production Center at Fernald, Ohio, operated for DOE by National Lead Co. of Ohio (NLO), a subsidiary of NL Industries, Inc., for conversion to the metal. There were no shipments of UF$_4$ to NLO in 1979. The metal was shipped from Fernald for eventual conversion to plutonium 239 for weapons use. NLO shipped 1,188 tons of depleted uranium metal in 1978, and 1,005 tons in 1979.

In 1978, a total of 2,935 tons of depleted UF$_4$ was shipped to Eldorado Nuclear Limited, Port Hope, Ontario, Canada; NL Industries, Albany, N.Y.; NMI, Concord, Mass.; and TNS, Jonesboro, Tenn., mainly for conversion to metal. In 1979 these companies received a total of 2,744 tons of depleted UF$_4$. These companies were all subcontractors to Aerojet Ordnance Co., Downey, Calif., and Honeywell Inc., New Brighton, Minn., which were under contract to the U.S. Department of Defense (DOD) to produce depleted uranium penetrators.

CONSUMPTION AND USES

Some 80% to 90% of depleted uranium metal was used in ordnance applications. Because of its density and pyrophoric properties on impact, depleted uranium was used as armor-piercing ammunition. Depleted uranium also provided a cost advantage because, as a byproduct of the enrichment process, it was provided without charge to DOD agencies to supply the companies which produced the ammunition for DOD.

Depleted uranium metal was used as shielding material in portable radiographic equipment which was in worldwide use for such applications as detecting voids and other defects in castings and pipeline welds. Many medical irradiation devices used for therapeutic purposes used depleted uranium radiation shielding. Prior to the use of depleted uranium in the construction of medical radiation devices, it was necessary to use relatively soft and bulky lead shielding. Now many of these devices use depleted uranium, not only as shielding, but as structural components of the instruments.

The aerospace-aircraft industry used depleted uranium metal as counterweights for control surfaces and landing gear. The aircraft industry used 47,000 pounds of depleted uranium in 1978 and twice that quantity, or 94,000 pounds, in 1979.

Satellites, missiles, and remotely piloted vehicles used depleted uranium ballast weights. Depleted uranium was also used in the manufacture of gyroscopes and inertial guidance platforms. Depleted uranium was used in the rims of these gyroscopes, and beryllium was used in the hubs and spokes. Both materials have similar coefficients of thermal expansion, which results in a compact, light gyroscope wheel with all significant mass properly distributed.

Depleted uranium metal was also used in making shipping containers for radioisotopes and spent nuclear fuel, sinker bars for oil well logging, vibration damping bars for machine tools, and research.

In some facilities which processed or handled UF$_6$, depleted UF$_6$ was used nondestructively to shake down equipment and thus avoid having to commit enriched UF$_6$. Depleted uranium was made into uranium dioxide (UO$_2$) pellets for use in prototype assemblies for atomic reactors. Also, depleted uranium was irradiated to produce new elements, such as plutionium 239. Depleted uranium was used as a power shaping medium; depleted uranium rods were placed in certain areas in a power reactor to absorb radiation and control the temperature of the reactor.

PRICES

The DOE base charge for depleted uranium, without a specification as to assay, was $2.50 per kilogram. The price of depleted uranium in 1978 was $2.75 to $3.25 per pound for derby metal. In 1979, the price of depleted uranium derby changed to $3.10 to $3.20 per pound.

STOCKS

The yearend DOE inventory of depleted UF_6 dropped from about 73,000 tons in 1977, to 68,000 tons in 1978. The 1979 yearend inventory was about 65,000 tons. The average assay of depleted UF_6 was 0.20% U_{235}. The total quantity of depleted uranium including the UF_6 was about 283,000 tons at the end of 1978 and about 295,000 tons at the end of 1979. Most of the stocks held by DOE were in the form of UF_6.

FOREIGN TRADE

In December 1979 DOE concluded a contract with the National Electrical Energy Agency of Italy for the sale of some 22,000 tons of depleted UF_6 (0.30% U_{235}). The shipments were scheduled to begin in October 1980, and were to go to Tricastin, France. Eurodif, at Tricastin, planned to further separate the U_{235} from the 0.30% depleted UF_6 to produce a 0.711% U_{235} product and 0.20% U_{235} (or less) tails.

When DOE received natural UF_6 for enrichment work, the customer had the option of getting the depleted uranium back along with the enriched uranium or leaving the depleted uranium. On this basis, Brazil received 9 tons of depleted uranium in 1978 and 11 tons were shipped to Korea. In 1979, Taiwan received 18 tons of depleted uranium, and 108 tons were shipped to the United Kingdom. Also in 1979, 139 tons of depleted uranium owned by the European Economic Community, also known as the Common Market, was shipped to TNS, Jonesboro, Tenn.

WORLD REVIEW

In addition to U.S. stocks, known stocks of depleted uranium held by other countries were estimated as follows:

Country	Short tons	
	1978	1979
Germany, Federal Republic of	[1]530	NA
Italy	[1]2,050	2,770
Netherlands	740	780
United Kingdom	22,000	22,000

NA Not available.

[1] Source: Uranium Resources, Production and Demand, Dec. 1979, a joint report by the Organization for Economic Cooperation and Development, Nuclear Energy Agency and the International Atomic Energy Agency.

TECHNOLOGY

Uranium ore is mined and sent to milling plants where it is mechanically and chemically processed to upgrade the uranium content. The product from the milling plant is called yellow cake (uranium oxide or U_3O_8). The yellow cake is processed to UF_6, which is a gas at about 56°C and atmospheric pressure. The UF_6 is shipped as a solid to one of three DOE enrichment facilities (Oak Ridge, Tenn., Paducah, Ky., or Portsmouth, Ohio), where it is enriched in U_{235} by a process known as gaseous diffusion.

Gaseous diffusion operates on the principle that the average velocities of gas molecules at a given temperature depend on their molecular mass. The molecules of the lighter isotopes of uranium such as U_{235} will contact the walls of a porous containment vessel more frequently than the molecules of the heavier isotopes and will diffuse through the walls faster. The barrier walls of the vessel contain hundreds of millions of submicroscopic openings per square inch. The degree of enrichment in a single stage is very small, but the desired enrichment level is achieved by repeating the process through hundreds of stages arranged in cascades. The process yields a product, UF_6, enriched in the isotope U_{235} (about 3% for commercial power reactors) and a waste product (tails) depleted in U_{235} (ideally 0.20%). The enriched UF_6 is shipped in 2-1/2-ton steel containers to commercial facilities where it is converted to uranium oxide (UO_2) for use in power reactors. The depleted UF_6 is stored in 14 ton cylinders or shipped to customers.

The depleted UF_6 can be reduced to UF_4 (greensalt) by reacting the UF_6 with hydrogen gas in electrically heated tower reactors. This reaction takes place as shown by the following equation:

$$UF_6 + H_2 \longrightarrow UF_4 + 2HF.$$

The reaction between the UF_6 and H_2 takes place at a temperature of 1,100°F (593°C). The solid UF_4 formed in the reaction drops to the bottom of the tower and is transferred to a storage hopper and from there to storage drums.

Reduction of UF_4 involves a reaction with magnesium, as shown by the following equation: $2 Mg + UF_4 \longrightarrow U + 2MgF_2$. The reaction takes place in an airtight cylinder with a flat bottom and a flanged top known as a reduction bomb. The bomb is lined with about 2 inches of very fine grained magnesium fluoride (MgF_2) powder or with a ceramic-coated graphite shell. UF_4 and Mg are mixed and placed in the bomb. The bomb is put into an electric furnace and heated at 1,200°F (649°C). The reaction, in which the fluorine disassociates from UF_4 to combine with the magnesium, normally occurs about 8 hours after the bomb is placed in the furnace. The heat generated by the reaction is sufficient to melt the uranium metal and the MgF_2, and the molten uranium metal, being heavier than the MgF_2, settles to the bottom of the bomb. Upon cooling, the uranium is formed into a massive piece of metal known as a derby. The MgF_2 or slag lies above the derby. The derby, slag, and old liner material are removed from the bomb and separated. The derby is freed of clinging slag and liner and sent to a furnace, where it is roasted at 1,200°F for 2 hours and then lowered into a water quenching tank. The cooled derby is cleaned to remove any remaining slag or magnesium inclusions. The clean derby is then ready to be rolled into sheets or melted and cast into various shapes.

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[1] Physical scientist, Section of Nonferrous Metals.

[2] U.S. Code of Federal Regulations. Title 10—Energy; Chapter I—Nuclear Regulatory Commission; Sections 40.25, 110.23, under General Licenses.

Vanadium

By George A. Morgan[1]

After declining in 1978, domestic vanadium output returned to more normal levels in 1979. Production ceased in Arkansas for most of 1978, but was reactivated in December of that year. World output increased in 1978-79. Excess vanadium stocks, which overhung the domestic market in 1977 and throughout most of 1978, were eliminated. Consumption and prices of vanadium both increased in 1979 as demand was up in the iron, steel, and aerospace industries. U.S. exports of ferrovanadium, vanadium ore and concentrate, and vanadium pentoxide declined considerably from those of 1978, while imports of ferrovanadium and vanadium pentoxide were up substantially.

Legislation and Government Programs.—Stockpile goals of 2,576 tons of vanadium contained in vanadium pentoxide and 10,095 tons of vanadium contained in ferrovanadium remained in effect for 1978-79. These goals were established October 1, 1976, by the General Services Administration. As of December 31, 1979, U.S. Government inventory of vanadium was 540 tons contained vanadium in the form of vanadium pentoxide.

Table 1.—Salient vanadium statistics

(Short tons of contained vanadium unless otherwise specified)

	1975	1976	1977	1978	1979
United States:					
Production:					
Ore and concentrate:					
Recoverable vanadium[1]	4,743	7,376	6,504	4,272	5,520
Value (thousand dollars)	$49,329	$81,279	$74,488	$56,776	$73,892
Vanadium oxides recovered[2]	4,860	6,197	5,208	5,204	5,758
Consumption	5,501	4,720	5,261	6,630	6,719
Exports:					
Ferrovanadium (gross weight)	1,018	1,210	658	1,3[illegible]	880
Ore and concentrates	215	99	192	191	101
Vanadium pentoxide, anhydride (gross weight)				1,239	630
Other compounds (gross weight)				291	316
Imports (general):					
Ferrovanadium (gross weight)	179	433	558	535	738
Ores, slags, residues	2,895	2,998	2,812	2,234	2,442
Vanadium pentoxide, anhydride	1,275	668	444	656	907
World production	28,471	[r]31,209	33,313	34,219	[e]41,420

[e]Estimate. [r]Revised.

[1]Recoverable vanadium contained in uranium and vanadium ores and concentrates received at mills, plus vanadium recovered from ferrophosphorus derived from domestic phosphate rock.

[2]Produced directly from all domestic sources and includes metavanadates.

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DOMESTIC PRODUCTION

Mine production of vanadium in the United States returned to normal levels in 1979 after experiencing a severe decline the previous year. Colorado was the leading producing State, followed by Utah. Union Carbide Corp.'s Hot Springs, Ark., mine and mill were reactivated in December 1978. Operations stopped at the Arkansas site because of depressed demand and excessive inventories. Union Carbide Corp. continued operation of its Rifle-Uravan complex in Colorado throughout the 2-year period. It processed uranium-vanadium ores, as well as uranium-vanadium liquors from Ranchers Exploration and Development Corp.'s leaching operation at Naturita, Colo. Ranchers Exploration and Development Corp. completed its mill-tailings leaching project at Naturita in April 1979. The company reported that recovery for fiscal year 1979 was 469 tons V_2O_5, compared with 448 tons V_2O_5 for fiscal year 1978. The company postponed indefinitely similar planned recovery of uranium and vanadium from old mill tailings at Durango, Colo., when a nuclear materials license was not received in time to meet contractual obligations.

Atlas Corp. operated its Moab, Utah, plant at full capacity at yearend 1979 after upgrading the facility. The company planned to begin processing richer uranium ores that it had discovered earlier in the year, some of which contain vanadium. Kerr McGee Corp. produced vanadium from ferrophosphorus at Soda Springs, Idaho. Cotter Corp., a subsidiary of Commonwealth Edison Co. of Chicago, commenced operations at its Canon City, Colo., mill in September 1979. The new facility will become the fifth mill to recover vanadium from domestic sources in the United States. Gulf Chemical and Metallurgical Corp. recovered vanadium oxide at its Texas City, Tex. plant from imported materials. Work continued on Pioneer Uravan Inc.'s mill in Disappointment Valley, Colo. Completion of the mill, which is expected to process 1,000 tons per day of uranium-vanadium ores, is planned for 1981.

Long Island Lighting Co. (LILCO) recovered high-grade ash containing 694 tons of vanadium pentoxide in 1979, compared with 643 tons in 1978. The company expected to improve vanadium recovery from the burning of residual oil with the implementation of water recovery systems at its two powerplants on Long Island, N.Y. Somex, Ltd., Bartlesville, Okla., a subsidiary of Engelhard Minerals & Chemicals Corp., was scheduled to recover 2,000 tons per year of vanadium pentoxide. Feed material is to be 35,000 tons per year of residues obtained from utility boilers in the United States and Western Europe.

Producers of vanadium additives and vanadium aluminum alloys for use by the steel and titanium industries were Engelhard Minerals & Chemicals Corp., Strasburg, Va.; Foote Mineral Co., Cambridge, Ohio; Reading Alloys, Inc., Robesonia, Pa.; Shieldalloy Corp. (a division of Metallurg, Inc.), Newfield, N.J.; The Pesses Co., Pulaski, Pa,; and Union Carbide Corp. at Marietta, Ohio, and Niagara Falls, N.Y.

Table 2.—Mine production and recoverable vanadium of domestic origin produced in the United States

(Short tons of contained vanadium)

Year	Mine production[1]	Recoverable vanadium[2]
1975	5,213	4,743
1976	8,076	7,276
1977	7,565	6,504
1978	4,446	4,272
1979	5,841	5,539

[1] Measured by receipts of uranium and vanadium ores and concentrates at mills, vanadium content.

[2] Recoverable vanadium contained in uranium and vanadium ores and concentrates received at mills, plus vanadium recovered from ferrophosphorus derived from domestic phosphate rock.

Table 3.—Production of vanadium oxides in the United States[1]

(Short tons)

Year	Gross weight	Oxide content[2]
1975	8,597	8,074
1976	10,836	11,063
1977	9,341	9,297
1978	9,785	9,290
1979	10,338	10,279

[1] Produced directly from all domestic sources; includes metavanadates.

[2] Expressed as equivalent V_2O_5.

CONSUMPTION, USES, AND STOCKS

Consumption is reported in tables 4-5. In addition to the consumers' stocks shown in table 4, producers' stocks of vanadium as fused oxide, precipitated oxide, metavanadate, metal, alloys, and chemicals totaled 2,401 tons of contained vanadium at yearend 1979, compared with 2,079 tons at yearend 1978.

Table 4.—Consumption and consumer stocks of vanadium materials in the United States

(Short tons of contained vanadium)

Type of material	1978		1979	
	Consumption	Ending stocks	Consumption	Ending stocks
Ferrovanadium[1]	5,997	900	6,068	879
Oxide	99	13	47	34
Ammonium metavanadate	31	9	38	6
Other[2]	503	52	566	67
Total	6,630	974	6,719	986

[1] Includes other vanadium-iron-carbon alloys.

[2] Consists principally of vanadium-aluminum alloy, plus relatively small quantities of other vanadium alloys and vanadium metal.

Table 5.—Consumption of vanadium in the United States, by end use

(Short tons of contained vanadium)

End use	1978	1979
Steel:		
Carbon	1,051	1,096
Stainless and heat resisting	32	45
Full alloy	1,506	1,522
High-strength low-alloy	2,440	2,410
Electric	W	--
Tool	858	852
Cast irons	59	62
Superalloys	27	20
Alloys (excluding steels and superalloys):		
Cutting and wear-resistant materials	W	W
Welding and alloy hard-facing rods and materials	11	10
Nonferrous alloys	467	563
Other alloys[1]	W	W
Chemical and ceramic uses:		
Catalysts	123	81
Other[2]	W	W
Miscellaneous and unspecified	56	58
Total	6,630	6,719

W Withheld to avoid disclosing individual company proprietary data, included in "Miscellaneous and unspecified."

[1] Includes magnetic alloys.

[2] Includes pigments.

PRICES

The price for domestic 98% fused vanadium pentoxide (metallurgical grade) quoted by Metals Week changed April 1, 1979, from 1978 prices of \$3.05 to \$4.04 per pound V_2O_5 to \$2.75 to \$4.04 per pound V_2O_5. Technical-grade, air-dried vanadium pentoxide changed from \$3.05 to \$3.52 per pound V_2O_5 to \$3.05-\$3.80 per pound V_2O_5. These new prices remained in effect for the remainder of the year. Price changes for several vanadium alloying products also became effective April 1, 1979: Carvan and Ferovan from \$6.05 to \$6.52 per pound contained vanadium; 70% to 80% vanadium-grade ferrovanadium from \$6.32 to \$6.58 per pound contained vanadium to \$6.80 to \$7.04 per pound contained vanadium.

FOREIGN TRADE

Strong domestic demand for vanadium resulted in a sharp decline in exports and a substantial increase in imports between 1978 and 1979, particularly of ferrovanadium and vanadium pentoxide. Imports of vanadium contained in ashes, residues, and slags increased to 2,442 tons in 1979 from 2,234 tons in 1978. The Republic of South Africa and Chile were the sources of slag for both years. None was received from the U.S.S.R.

Table 6.—U.S. exports of vanadium, by country

(Thousand pounds and thousand dollars)

Destination	Ferrovanadium (gross weight)		Vanadium ore and concentrate (vanadium content)		Vanadium compounds (gross weight)			
					Pentoxide (anhydride)		Other	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Valu
1978								
Argentine	--	--	12	61	--	--	1	[illegible]
Australia	--	--	--	--	1	3	--	--
Austria	--	--	--	--	645	713	--	--
Belgium-Luxembourg	8	7	--	--	--	--	--	--
Brazil	--	--	31	128	139	406	--	--
Canada	418	1,809	211	760	61	147	370	[illegible]
China:								
Mainland	110	451	--	--	--	--	--	--
Taiwan	81	329	--	--	4	7	1	[illegible]
Czechoslovakia	--	--	--	--	352	354	--	--
Dominican Republic	--	--	--	--	--	--	22	[illegible]
France	3	10	--	--	--	--	12	[illegible]
Germany, Federal Republic of	22	82	--	--	695	1,339	--	--
Hong Kong	9	37	--	--	--	--	--	--
India	2	8	13	49	65	148	--	--
Indonesia	11	37	5	25	15	73	6	[illegible]
Japan	1,583	5,788	48	274	105	234	29	[illegible]
Korea, Republic of	(1)	1	--	--	--	--	3	[illegible]
Malaysia	1	2	--	--	--	--	--	--
Mexico	49	208	62	273	106	192	24	[illegible]
Netherlands	80	336	--	--	--	--	6	[illegible]
Norway	--	--	--	--	122	241	--	--
Philippines	2	8	--	--	5	20	--	--
Qatar	59	237	--	--	--	--	--	--
Sweden	184	636	--	--	--	--	--	--
Trinidad and Tobago	--	--	--	--	--	--	12	[illegible]
United Kingdom	--	--	--	--	38	36	73	[illegible]
Venezuela	--	--	--	--	4	16	13	[illegible]
Total	2,617	9,986	382	1,570	2,477	3,931	582	[illegible]
1979								
Australia	3	8	--	--	(1)	1	--	--
Belgium	--	--	--	--	4	18	3	[illegible]
Brazil	--	--	--	--	137	329	--	--
Canada	583	2,843	85	291	91	201	--	--
Chile	--	--	--	--	--	--	220	[illegible]
China: Taiwan	--	--	--	--	12	27	1	[illegible]
Germany, Federal Republic of	200	870	--	--	157	169	15	[illegible]
Hong Kong	2	10	--	--	--	--	--	--
India	--	--	12	52	22	55	--	--
Indonesia	1	6	--	--	14	48	--	--
Italy	--	--	--	--	200	445	--	--
Japan	711	2,957	80	392	227	538	77	[illegible]
Korea, Republic of	71	320	--	--	2	9	--	--
Malaysia	--	--	--	--	--	--	1	[illegible]
Mexico	49	199	14	89	364	1,104	88	[illegible]
Nicaragua	--	--	--	--	--	--	1	[illegible]
Peru	--	--	--	--	16	23	--	--
Philippines	9	55	--	--	12	53	--	--
Singapore	1	2	--	--	--	--	--	--
South Africa, Republic of	--	--	--	--	--	--	(1)	[illegible]
Spain	22	82	--	--	--	--	--	--
Sweden	33	129	--	--	--	--	30	[illegible]
Thailand	--	--	--	--	--	--	(1)	[illegible]
United Kingdom	--	--	--	--	--	--	15	[illegible]
Uruguay	--	--	--	--	--	--	7	[illegible]
Venezuela	74	391	--	--	1	5	196	[illegible]
Total[2]	1,759	7,861	201	824	1,259	3,024	682	[illegible]

[1] Less than 1/2 unit.

[2] Data may not add to totals shown because of independent rounding.

Table 7.—U.S. imports of ferrovanadium, by country

(Thousand pounds and thousand dollars)

Country	1978 Gross weight	1978 Vanadium content	1978 Value	1979 Gross weight	1979 Vanadium content	1979 Value
General imports:						
Austria	44	36	199	--	--	--
Canada	364	294	1,614	571	447	2,657
Germany, Federal Republic of	216	147	813	451	279	1,543
Norway	214	107	527	--	--	--
South Africa, Republic of	9	7	32	--	--	--
Spain	15	11	51	--	--	--
Sweden	207	168	834	188	152	839
United Kingdom	--	--	--	264	155	928
Total[1]	1,070	772	4,071	1,475	1,033	5,967
Imports for consumption:						
Canada	364	294	1,614	571	447	2,657
Germany, Federal Republic of	216	147	813	451	279	1,543
Norway	319	153	741	--	--	--
South Africa, Republic of	9	7	32	--	--	--
Spain	15	11	51	--	--	--
Sweden	207	168	834	188	152	839
United Kingdom	--	--	--	264	155	928
Total[1]	1,130	782	4,086	1,475	1,033	5,967

[1] Data may not add to totals shown because of independent rounding.

Table 8.—U.S. imports of vanadium pentoxide (anhydride), by country

Country	1978 Gross weight (pounds)	1978 Vanadium content (pounds)	1978 Value	1979 Gross weight (pounds)	1979 Vanadium content (pounds)	1979 Value
General imports:						
Canada	--	--	--	14,000	7,842	$1,300
Denmark	58,397	32,714	$63,302	--	--	--
Finland	250,002	140,051	488,869	1,072,095	600,588	2,559,046
South Africa, Republic of	2,005,442	1,123,449	3,396,617	2,151,724	1,205,396	4,745,500
United Kingdom	27,494	15,402	28,041	3	2	416
Total	2,341,335	1,311,616	3,976,829	3,237,822	1,813,828	7,306,262
Imports for consumption:						
Canada	--	--	--	14,000	7,842	1,300
Denmark	58,397	32,714	63,302	--	--	--
Finland	250,002	140,051	488,869	1,072,095	600,588	2,559,046
South Africa, Republic of	2,303,324	1,290,322	3,843,558	2,151,724	1,205,396	4,745,200
United Kingdom	27,494	15,402	28,041	3	2	416
Total	2,639,217	1,478,489	4,423,770	3,237,822	1,813,828	7,305,962

WORLD REVIEW

In addition to the countries listed in table 9, some others had relatively small vanadium production from secondary, waste, or byproduct sources. Japan, the Federal Republic of Germany, Sweden, and possibly France and India, produced vanadium from several such sources.

World capacity to produce vanadium increased, and continued to exceed the rate of world vanadium consumption. However, several countries, notably the Federal Republic of Germany, have announced plans to stockpile vanadium.

Australia.—Agnew Clough Ltd., constructed access roads and installed primary and secondary crushers at its open pit vanadium mine at Coates Siding, 40 miles east of Perth. Initial production is to be about 1,245 tons per year of vanadium pentoxide. A contract valued at $20 million for a 7-year supply of vanadium from the project was signed by Nissho-Iwai Co., Ltd. A minimum of 550 tons per year of vanadium pentoxide is to be shipped commencing April 1980.

Western Mining Corp. Ltd., released

Table 9.—Vanadium: World production from ores and concentrates, by country

(Short tons of contained vanadium)

Country	1976	1977	1978[p]	1979[e]
Chile[e] [1]	1,199	950	760	500
China, Mainland[e]	NA	NA	2,200	7,200
Finland (in vanadium pentoxide product)	[r]1,598	2,055	3,092	3,100
Norway[e]	580	[r]590	510	500
South Africa, Republic of:[2]				
Content of pentoxide and vanadate product[e]	[r]3,169	[r]4,059	4,023	4,300
Content of vanadiferous slag product[e]	[r]7,716	[r]8,329	8,377	9,300
Total	10,885	12,388	[e]12,400	13,600
South-West Africa, Territory of (in lead vanadate concentrate)[3]	[r]771	826	485	--
U.S.S.R. [e]	8,800	10,000	10,500	11,000
United States (recoverable vanadium)	7,376	6,504	4,272	[4]5,520
Total	[r]31,209	33,313	34,219	41,420

[e]Estimate. [p]Preliminary. [r]Revised. NA Not available.

[1]Based on U.S. imports of vanadium-bearing slag.

[2]For 1976 and 1977 the Republic of South Africa officially reported the undistributed total production of vanadium in pentoxides and vanadate products as well as in vanadium-bearing slags. Data on vanadium content of vanadium slag are estimated on the basis of a reported tonnage of vanadium-bearing slag (gross weight) multiplied by an assumed grade of 14% vanadium. Vanadium content of pentoxide and vanadate products represents the difference between the reported total and the calculated estimate for vanadium in slag.

[3]Data represent output of South West Africa Co. Ltd. for the years ending June 30 of that stated.

[4]Reported figure.

plans for developing the Yeelirrie uranium-vanadium deposit in Western Australia. The ore is located in a horizontal formation over a wide area at shallow depth, and is relatively easy to mine. Alkaline leaching will be employed, although availability of water may be a constraining factor. Full-scale operation as an open pit mine is projected to reach 1,120 tons per year vanadium pentoxide by yearend 1984.

Brazil.—A mineralized zone containing 100 million tons of titanium- and vanadium-bearing material was discovered in the Campo Alegre de Lourdes area between the States of Bahia and Piaui. Vanadium content was reported at 0.7% V_2O_5. About 500 million tons of ore is expected to be delineated.[2]

China (Mainland).—A plant for processing mixed slags for recovery of vanadium began operating at yearend 1978. Slag is obtained from blast furnace reduction of vanadiferous-titaniferous-magnetite by the Panzhihua Steelworks in Szechan Province.[3] Research was underway for direct treatment of the magnetite for vanadium recovery using a salt roast process.

Finland.—Vanadium pentoxide production increased by about 50% in 1978. Rautaruukki Oy's new Mustavaara open pit operation in northeastern Finland came into full production following alleviation of problems with the sintering furnace. The mine was designed to operate as an open pit for 20 years.

Japan.—Production of ferrovanadium was estimated at 4,400 tons in 1979, compared with 3,571 tons in 1978 and 2,834 tons in 1977; consumption was reported as 4,522 tons in 1978 and 4,614 tons in 1977. Imports were 1,865 tons in 1978, 967 tons in 1977, and 1,719 tons in 1976. The United States, the Federal Republic of Germany, and Austria were the principal suppliers. Japan imported 2,928 tons of vanadium pentoxide in 1978, over 90% of which came from the Republic of South Africa.[4] [5]

Taiyo Mining and Industrial Co. Ltd., installed a spent-catalyst-recovery plant at its Akao, Hyogo Prefecture works. Recovery of 440 tons per year of vanadium pentoxide is expected, as well as quantities of molybdenum, aluminum, nickel, and cobalt, from a throughput of 4,500 tons per year of molybdenum-based catalysts used in heavy-oil desulfurization.

Poland.—A consortium of banks in the Federal Republic of Germany has extended a $430 million credit to Poland for development of a vanadiferous-titaniferous-magnetite deposit. Metallgesellschaft AG signed an agreement for receipt of the vanadium and titanium. The Government of the Federal Republic of Germany is covering a portion of the loan.[6]

South Africa, Republic of.—The Republic of South Africa was the world's largest producer of vanadium in 1978-79 with output in the forms of slag, polyvanadate, metavanadate, and fused pentoxide. Highveld Steel and Vanadium Corp. Ltd., is to install a ninth roasting unit at its Witbank operation in Transvaal. Completion of the expansion program is expected by 1981, and will increase production of iron, steel, and vanadium slag by 10%. Plans are also being prepared for the 10th and final prereduction kiln at Witbank.

South-West Africa, Territory of (Namibia).—South West Africa Co, Ltd. (SWACO), ceased production from its underground Berg Aukas mine about midyear 1978. Decling ore grade and low metal prices were the primary reasons for placing the mine on a "care and maintenance" status. Above-ground stocks continued to be processed.

Spain.—Spain's first production of ferrovanadium was initiated by Ferroaleaciones Asturianes at Aviles in 1978. A 9% duty on ferrovanadium imports was declared by the Ministry of Commerce in support of the company's 800-ton-per-year output in 1979. The Federal Republic of Germany and Austria have been Spain's principal sources of ferrovanadium.

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[1] Physical scientist, Section of Ferrous Metals.

[2] Mining Journal (London). Brazil: Titanicm Find. Aug. 24, 1979, p. 146.

[3] Metal Bulletin (London). China: Progress At Many Works. No. 6373, Mar. 13, 1979, p. 41.

[4] Japan Metal Journal (Tokyo). Ferrovanadium Production and Consumption Expected To Rise This Year. V. 9, No. 13, Mar. 26, 1979, pp. 9-10.

[5] ———. Net Imports of Ferroalloys In 1978 Tops 290,000 Tons. V. 9, No. 10, Mar. 5, 1979, pp. 8-9.

[6] Metal Bulletin (London). Germans Aid Polish Vanadium. No. 6425, Sept. 21, 1979, p. 25.

Vermiculite

A. C. Meisinger[1]

U.S. production of vermiculite concentrate in 1979 showed a 3% recovery in quantity sold and used by producers (346,000 tons) from the 6% decline in 1978. Value of production in 1979 continued to increase, and was 12% higher than in 1978, and 18% above that in 1977.

Vermiculite in 1979 was mined and beneficiated from deposits in Montana, South Carolina, and a newly developed mine in Virginia. The only operation in Texas was idle in 1979.

Exfoliated vermiculite was produced at 47 plants in 30 States in 1979, and the quantity sold and used was 4,000 tons (1.5%) above the 1978 total from 49 plants in 29 States. Value of exfoliated vermiculite sold and used in 1979 was $51.2 million compared with $49 million in 1978. W. R. Grace & Co. continued to be the leading domestic producer of vermiculite concentrate and exfoliated.

The principal uses of exfoliated vermiculite in 1979 were for concrete aggregate, 23%; fertilizer carriers, 17%; block insulation, 16%; loose fill insulation, 15%; horticulture and soil conditioning, 14%; and premixes, 12%.

World production of vermiculite was 607,000 tons in 1979, a slight decline from the 616,000 tons produced in 1978.

Table 1.—Salient vermiculite statistics

(Thousand short tons and thousand dollars)

	1975	1976	1977	1978	1979
United States:					
Sold and used by producers:					
Concentrate	330	304	359	337	346
Value	$13,800	$14,000	$18,600	$19,700	$22,000
Average value per ton[1]	$41.82	$46.05	$51.81	$58.46	$63.59
Exfoliated	235	270	321	270	274
Value	$36,300	$42,300	[r]$50,500	$49,000	$51,200
Average value per ton[1]	$154.47	$156.67	[r]$157.82	$181.48	$186.86
Exports to Canada	45	41	[e]45	[e]29	NA
Imports from the Republic of South Africa	33	40	[e]40	[e]28	NA
World: Production[2]	588	[r]576	577	616	[e]607

[e] Estimated. [r] Revised. NA Not available.

[1] Based on rounded data.

[2] Excludes production by centrally planned economy countries.

DOMESTIC PRODUCTION

U.S. production of vermiculite concentrate in 1979 was 346,000 tons valued at $22 million, an increase of 3% in quantity sold and used and an increase of 12% in value over that in 1978. U.S. output in 1978 had decreased 6% in quantity from that in 1977.

The principal vermiculite mining and beneficiating operations in 1979 were those of W. R. Grace & Co. at Libby, Mont., and Enoree, S. C. Vermiculite was also mined and processed in 1979 by Patterson Vermiculite Co. near Enoree, S. C., and by Virginia Vermiculite, Ltd., in Louisa County, Va., which completed its first year of production. The Volite Company, Llano, Tex., was inactive during the year.

Exfoliated vermiculite output in 1979 increased 4,000 tons in quantity sold and used over that in 1978, and was produced in 47 plants in 30 States compared with 49 plants in 29 States in 1978 and 51 plants (revised) in 1977. The value of exfoliated vermiculite sold and used by producers in 1979 was $51.2 million, an increase of 4.5% over that in 1978. Producers and exfoliation plant locations are shown in table 3. Vermiculite imported from the Republic of South Africa (quantity unknown) was also exfoliated in domestic plants in 1979.

The principal producing States, in descending order of exfoliated vermiculite production in 1979, were Ohio, South Carolina, Texas, Florida, California, New Jersey, Illinois, and Pennsylvania. In 1978, Illinois was ranked fifth and California was ranked sixth.

Table 2.—Exfoliated vermiculite sold and used, by end use

Use	1977		1978		1979	
	Short tons	Percent of total	Short tons	Percent of total	Short tons	Percent of total
Aggregates:						
Concrete	65,900	21	66,900	25	63,200	23
Plaster	[r]3,200	1	4,400	2	2,800	1
Premixes[1]	[r]30,200	9	22,200	8	33,400	12
Total[2]	[r]99,300	31	93,500	35	99,400	36
Insulation:						
Loose fill	74,900	23	41,200	15	40,900	15
Block	[r]49,400	15	42,500	16	44,500	16
Packing	200	--	200	--	200	--
Total[2]	[r]124,500	39	83,900	31	85,600	31
Agriculture:						
Horticulture and soil conditioning	[r]41,000	13	41,800	15	38,900	14
Fertilizer carrier	[r]48,600	15	45,600	17	45,400	17
Total[2]	[r]89,600	28	87,400	32	84,300	31
Other uses[3]	[r]7,500	2	5,500	2	4,700	1
Grand total[2]	321,000	100	270,000	100	274,000	100

[r] Revised.

[1] Includes acoustic and fireproofing uses, texturizing, and moisture sealants.

[2] Data may not add to totals shown because of independent rounding.

[3] Includes cryogenic, refractory, and other industrial applications.

Table 3.—Vermiculite exfoliating plants in the United States in 1979

Company	State	County	Nearest city or town
Brouk Co	Missouri	St. Louis	St. Louis.
Cleveland Builders Supply Co., Cleveland Gypsum Co., Div.	Ohio	Cuyahoga	Cleveland.
Diversified Insulation, Inc	Minnesota	Hennepin	Minneapolis.
J. P. Austin Assoc., Inc	Pennsylvania	Allegheny	Beaver Falls.
W. R. Grace & Co., Construction Products Div.	Alabama	Jefferson	Irondale.
	Arizona	Maricopa	Phoenix.
	Arkansas	Pulaski	North Little Rock.
	California	Alameda	Newark.
	do	Orange	Santa Ana.
	Colorado	Denver	Denver.
	Florida	Broward	Pompano Beach.
	do	Duval	Jacksonville.
	do	Hillsborough	Tampa.
	Illinois	Du Page	West Chicago.
	Kentucky	Campbell	Newport.
	Louisiana	Orleans	New Orleans.
	Maryland	Prince Georges	Muirkirk.
	Massachusetts	Hampshire	Easthampton.
	Michigan	Wayne	Dearborn.
	Minnesota	Hennepin	Minneapolis.
	Missouri	St. Louis	St. Louis.
	Nebraska	Douglas	Omaha.

Table 3.—Vermiculite exfoliating plants in the United States in 1979 —Continued

Company	State	County	Nearest city or town
	New Jersey	Mercer	Trenton.
	New York	Cayuga	Weedsport.
	North Carolina	Guilford	High Point.
	Oklahoma	Oklahoma	Oklahoma City.
	Oregon	Multnomah	Portland.
	Pennsylvania	Lawrence	New Castle.
	South Carolina	Greenville	Kearney.
	do	do	Travellers Rest.
	Tennessee	Davidson	Nashville.
	Texas	Bexar	San Antonio.
	do	Dallas	Dallas.
	Wisconsin	Milwaukee	Milwaukee.
International Vermiculite Co	Illinois	Macoupin	Girard.
Koos, Inc	Wisconsin	Kenosha	Kenosha.
Mica Pellets, Inc	Illinois	DeKalb	DeKalb.
Patterson Vermiculite Co	South Carolina	Laurens	Lanford.
Robinson Insulation Co	Montana	Cascade	Great Falls.
	North Dakota	Ward	Minot.
The Schundler Co	New Jersey	Middlesex	Metuchen.
O. M. Scott	Ohio	Union	Marysville.
Strong-Lite Products	Arkansas	Jefferson	Pine Bluff.
Verlite Co	Florida	Hillsborough	Tampa.
Vermiculite of Hawaii, Inc	Hawaii	Honolulu	Honolulu.
Vermiculite-Intermountain, Inc	Utah	Salt Lake	Salt Lake.
Vermiculite Products, Inc	Texas	Harris	Houston.

CONSUMPTION AND USES

Major end-use categories of exfoliated vermiculite in 1979 were aggregates, 36% of total consumption (up 1 percentage point from 1978); insulation, 31% (no change); and agriculture, 31% (down 1 percentage point).

Aggregate uses totaled 99,400 tons sold and used in 1979, a 6% increase over that in 1978; insulation uses increased 2% over that in 1978; and agricultural uses decreased 4% from that in 1978. Other uses in 1979 totaled 4,700 tons, a decrease of 15% from that in 1978.

The 16% decrease in U.S. consumption of exfoliated vermiculite from 321,000 tons in 1977 to 270,000 tons in 1978 was caused primarily by a 33% decline in consumption of loose fill and block insulation, which together accounted for 83,700 tons in 1978, compared with 124,300 tons in 1977. The slight recovery in U.S. consumption in 1979 was due primarily to a 50% increase in use of aggregate premixes (fireproofing, texturizing, and sealant products) which totaled 33,400 tons, compared with 22,200 tons in 1978 and 30,200 tons in 1977.

PRICES

The average value of vermiculite concentrate sold and used by U.S. producers in 1979 was $63.59 per ton, an increase of 9% over that reported in 1978. Compared with that in 1977, the 1978 increase was 13%.

The average value of exfoliated vermiculite sold and used in 1979 was $186.86 per ton, an increase of 3% over that in 1978. Compared with that in 1977, the 1978 increase was 15%.

Engineering and Mining Journal quoted 1979 yearend prices for unexfoliated vermiculite as follows: Per short ton, f.o.b. mine, Montana and South Carolina, domestic, $59 to $92; and Republic of South Africa, $50 to $100, c.i.f. Atlantic ports. For comparison, yearend 1978 quoted prices were $48 to $85 for domestic and $70 to $90 for Republic of South Africa.

FOREIGN TRADE

The United States annually imports large quantities of vermiculite from the Republic of South Africa, and exports vermiculite to Canada. However, tonnage data in 1979 were not available.

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[1] Industry economist, Section of Nonmetallic Minerals.

Table 4.—Vermiculite: World production, by country[1]

(Short tons)

Country	1976	1977	1978[p]	1979[e]
Argentina	4,517	5,139	5,800	5,900
Brazil	1,043	7,532	21,617	22,000
Egypt	--	--	654	700
India	[r]3,786	3,172	1,991	2,000
Japan[e]	14,000	15,000	16,000	17,000
Kenya	3,964	4,762	2,054	2,200
South Africa, Republic of	244,798	182,343	230,485	[2]211,173
Tanzania[e]	20	20	20	20
United States (sold and used by producers)	304,000	359,000	337,000	[2]346,000
Total[3]	[r]576,000	577,000	616,000	607,000

[e]Estimate. [p]Preliminary. [r]Revised.

[1] Excludes production by centrally planned economy countries.

[2] Reported figure.

[3] Data may not add to totals shown because of independent rounding.

Zinc

By V. Anthony Cammarota, Jr.,[1] John M. Lucas,[1]
and Barbara M. Gorby[2]

In 1978, both mine and metal production declined as mines closed and smelters cut back production to reduce stocks. However, consumption increased and imports of both concentrate and metal made up the shortfall. The closed mines were put on a care and maintenance status, primarily because of low zinc prices. Exploration and development continued in Tennessee, Kentucky, and Wisconsin, and a significant sulfide deposit was reported in Maine. Consumption of slab zinc was up over that of 1977. The decline in the amount of zinc used in diecastings, especially in the automotive industry, was offset by increased use of zinc in the galvanizing sector.

In 1979, mine production declined further to the lowest level since 1932, but metal production increased as a new smelter became fully operational. The largest smelter in the United States, and the world's fourth largest, closed in December. Imports of concentrate were higher to supply feed to the the smelters, but imports of slab zinc declined to about the 1977 level. Consumption of slab zinc declined as the economy

Table 1.—Salient zinc statistics

	1975	1976	1977	1978	1979
United States:					
Production:					
Domestic ores, recoverable content metric tons	425,792	439,543	407,889	302,669	267,341
Value thousands	$366,097	$358,541	$309,338	$206,854	$219,841
Slab zinc:					
From domestic ores metric tons	279,376	346,429	322,208	267,350	255,344
From foreign ores do.	118,018	106,125	86,156	139,348	217,137
From scrap do.	52,513	62,192	45,914	34,774	53,212
Total	449,907	514,746	454,278	441,472	525,693
Secondary zinc[1] do.	204,402	276,089	284,065	304,047	316,818
Exports of slab zinc do.	6,257	3,187	215	723	279
Imports (general):					
Ores (zinc content) do.	131,530	88,101	111,410	188,003	224,952
Slab zinc do.	345,127	648,174	523,206	617,840	527,212
Stocks, December 31:					
Producer do.	67,745	87,962	[r]83,700	37,928	59,066
Consumer do.	97,319	109,900	[r]86,477	99,325	93,334
Government stockpile do.	349,914	349,440	347,826	345,872	345,864
Reprocessed GSA zinc[2] do.	3,123	--	--	--	--
Consumption:					
Slab zinc do.	839,445	1,028,876	999,505	1,060,985	1,000,606
All classes do.	1,117,484	1,384,244	1,367,704	1,441,810	1,394,314
Price: Prime Western, cents per pound (delivered)	38.96	37.01	34.39	30.97	37.30
World:					
Production:					
Mine thousand metric tons	5,850	5,690	5,906	5,878	5,996
Smelter[3] do.	5,013	5,362	5,527	5,614	5,998
Price: Prime Western grade, London cents per pound	33.76	32.38	26.71	26.88	33.59

[r] Revised.
[1] Excludes redistilled slab zinc.
[2] Included in total amount withdrawn from Government stockpile.
[3] Primary metal production only; includes secondary metal production where inseparably included in country total.

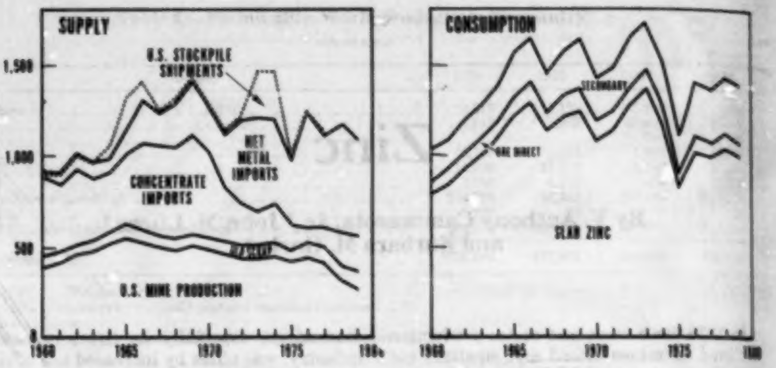

Figure 1.—Trends in supply and consumption in the United States.

slowed in the second half of the year.

Quoted prices for Prime Western Grade zinc increased from 29 cents per pound in February 1978 to 40.5 cents in mid-1979, but by yearend had fallen to 37.5 cents. Producer stocks rose significantly in 1979, while consumer stocks declined somewhat.

Legislation and Government Programs.—The stockpile goal for zinc remained at 1,191,134 tons through 1979.

The Environmental Protection Agency (EPA) issued final regulations limiting the content of pollutants including zinc, in effluents from ore mining and milling operations. The maximum zinc content was set at 1.5 milligrams per liter per day for mine drainage and two-thirds that amount for mill effluent. These regulations, effective July 11, 1978, represent the degree of control achievable by the application of the best practicable control technology available. In its economic analysis, EPA did not expect the regulations to affect significantly prices, production, and capital availability, and expected little impact on the local economies or balance of trade.

In December 1977, the Lead-Zinc Producers Committee filed a petition with the U.S. International Trade Commission seeking temporary relief from excessive imports. On June 20, 1978, the Commission found that increased imports of unalloyed, unwrought zinc were not a substantial cause of serious injury or a threat thereof, to the domestic industry for purposes of the import relief provisions of the Trade Act of 1974.

In accordance with the Trade Act of 1974, the Department of Labor investigated the eligibility of certain workers in the zinc industry to apply for worker adjustment assistance. The Department found that increased imports of zinc materials led to worker layoffs at about 19 mines, 2 smelters, and 2 plants that processed zinc-bearing materials in 1978-79. Benefits to eligible employees provide for such items as training, assistance in finding a new job, and a relocation allowance.

The International Lead and Zinc Study Group held an extraordinary session in July 1978 to evaluate the zinc situation in addition to its regular session in Geneva, Switzerland, in November. The Study Group found that the zinc market improved in 1978 through reduction in producer stocks, and noted the rapid rise in zinc exports to Socialist countries, and the closure of about 20 mines with a total production rate of about 150,000 tons of zinc per year. At its annual session in Geneva in October 1979, the Study Group was concerned about the supply of zinc metal exceeding demand and the resultant increase in stocks in 1979-80.

Table 2.—Zinc statistics, 1900-79

(Metric tons, except as noted)

Year	World		United States								
	Smelter production (thousand metric tons)	Mine production (thousand metric tons)	Slab zinc production		Mine production	General Imports		Exports		Consumption		Price, cents per pound
			Primary	Secondary		Slab zinc	Ore, zinc content	Slab zinc	Ore, zinc content	Slab zinc	Ore, direct	
1900	479	NA	112,988	NA	150,546	892	NA	20,322	38,158	90,173	NA	4.30
1901	511	NA	127,752	NA	167,646	252	NA	3,075	40,058	128,529	NA	4.00
1902	547	NA	142,962	NA	192,922	406	NA	2,987	50,500	138,511	NA	4.76
1903	574	NA	144,441	NA	180,194	182	NA	1,280	35,758	140,062	NA	5.25
1904	629	NA	169,373	NA	201,961	309	NA	9,306	32,578	164,129	NA	5.00
1905	660	NA	184,929	NA	213,003	388	NA	5,004	28,074	181,824	54,708	5.80
1906	704	NA	203,908	NA	201,147	828	22,749	4,257	25,147	200,289	60,088	6.20
1907	738	NA	226,689	6,898	225,824	1,550	23,691	511	18,468	205,908	51,647	5.50
1908	723	NA	190,898	6,495	212,758	799	17,840	1,119	22,665	194,289	43,549	4.20
1909	775	NA	232,022	8,412	277,075	8,077	23,165	308	11,299	245,602	49,114	5.40
1910	810	NA	244,200	11,597	297,286	1,778	15,155	8,386	17,862	223,062	45,896	5.40
1911	894	NA	259,982	12,740	318,215	8,088	13,523	13,023	16,594	254,065	41,841	5.70
1912	968	NA	307,260	23,645	343,656	10,083	13,516	6,808	21,182	308,758	58,089	6.90
1913	1,015	NA	314,499	23,579	358,684	5,524	8,549	12,234	16,089	287,956	64,067	5.60
1914	876	NA	320,281	18,689	377,082	797	8,737	67,594	10,079	272,140	64,064	5.10
1915	837	NA	444,084	27,001	533,087	820	28,471	119,218	755	280,991	72,186	14.20
1916	978	NA	606,311	28,105	636,089	621	94,352	187,211	71	416,686	81,897	13.60
1917	1,086	1,101	607,427	15,272	647,150	233	77,089	190,689	1,197	375,251	88,517	8.90
1918	822	935	469,656	8,987	577,052	32	23,158	96,751	68	354,458	98,229	8.00
1919	659	898	422,515	17,915	497,905	64	12,221	132,718	--	298,886	90,909	7.00
1920	722	855	420,280	19,287	532,988	7,418	12,086	108,661	--	293,040	106,122	7.80
1921	472	511	181,801	15,942	232,829	6,777	2,067	4,495	--	184,708	51,917	4.70
1922	711	804	321,286	29,926	428,220	47	910	31,571	1,688	338,462	86,104	5.70
1923	946	980	462,068	35,774	554,009	19	1,904	29,866	2,544	405,071	106,633	6.70
1924	1,002	1,463	469,322	32,192	578,763	23	1,368	60,165	384	416,652	99,207	6.30
1925	1,128	1,354	519,768	35,544	644,870	22	12,280	60,264	62,551	453,680	100,908	7.66
1926	1,218	1,608	551,028	37,012	702,672	20	13,215	38,936	86,411	505,328	117,744	7.37
1927	1,306	1,604	537,522	38,813	651,850	54	8,630	41,454	42,380	468,446	110,628	6.25
1928	1,401	1,591	546,652	44,149	630,648	2	1,512	22,942	4,009	568,251	112,573	6.03
1929	1,451	1,751	567,396	42,963	657,236	205	18,073	13,073	64	575,437	125,296	6.49

See footnotes at end of table.

Table 2.—Zinc statistics, 1900-79 —Continued

(Metric tons, except as noted)

Year	World		United States									
	Smelter production (thousand metric tons)	Mine production (thousand metric tons)	Slab zinc production		Mine production	General Imports		Exports		Consumption		Price, cents per pound
			Primary	Secondary		Slab zinc	Ore, zinc content	Slab zinc	Ore, zinc content	Slab zinc	Ore, direct	
1930	1,394	1,567	451,819	31,614	540,161	255	23,441	4,203	--	409,050	94,856	4.56
1931	997	1,045	264,894	19,618	372,234	249	708	583	12	335,658	67,614	3.64
1932	781	904	187,922	13,352	258,757	281	1,727	5,870	--	234,961	49,893	2.88
1933	983	1,134	278,671	27,294	348,613	1,715	1,935	1,039	734	317,787	64,974	4.03
1934	1,168	1,253	329,843	17,863	398,006	1,565	12,952	4,631	3,285	326,496	69,246	4.16
1935	1,332	1,451	381,593	25,991	469,834	4,032	9,544	1,467	418	429,090	77,766	4.33
1936	1,464	1,612	446,455	38,291	522,152	10,578	156	34	222	527,962	87,082	4.90
1937	1,623	1,751	505,215	46,769	568,226	33,755	7,994	226	285	553,383	101,262	6.52
1938	1,566	1,755	404,914	28,679	468,745	6,559	16,858	--	122	381,925	62,686	4.61
1939	1,650	1,789	460,157	45,748	529,621	28,030	32,749	4,006	275	567,898	77,016	5.12
1940	1,620	1,927	612,599	44,377	603,340	14,940	163,584	71,750	406	665,018	87,014	6.34
1941	1,749	2,072	745,724	53,960	679,595	31,347	262,370	81,020	--	750,637	122,302	7.48
1942	1,800	2,094	809,093	48,258	696,741	33,016	384,214	121,507	--	660,584	104,328	8.25
1943	1,840	2,018	854,849	43,740	675,123	50,943	489,017	88,395	1	740,968	104,054	8.25
1944	1,622	2,059	788,618	44,486	651,941	57,721	383,462	19,573	--	806,148	129,063	8.25
1945	1,302	1,616	693,598	44,672	557,336	88,102	346,290	7,060	--	773,204	118,834	8.25
1946	1,392	1,583	660,668	40,384	521,490	95,021	246,805	42,841	81	735,039	121,558	8.73
1947	1,599	1,769	728,011	54,016	578,428	65,600	270,304	96,769	1,274	718,374	132,379	10.50
1948	1,706	1,858	714,648	56,536	571,506	84,579	239,681	59,454	3,218	741,837	120,337	13.58
1949	1,825	1,910	739,158	49,932	588,145	115,114	218,794	53,260	2,654	645,771	79,961	12.15
1950	1,969	2,150	765,181	60,754	565,516	141,497	252,717	11,718	1,034	877,369	121,957	13.88
1951	2,141	2,369	799,804	44,141	617,964	79,871	274,675	33,121	2,803	847,284	121,422	17.99
1952	2,232	2,585	820,580	49,996	604,186	104,966	407,903	52,357	3,057	773,632	99,134	16.21
1953	2,359	2,667	881,077	47,967	496,620	212,804	466,043	16,301	2,679	894,418	107,269	10.86
1954	2,449	2,658	727,948	61,700	429,526	142,299	418,157	22,674	--	802,223	90,035	10.69
1955	2,658	2,903	874,076	59,912	466,902	177,582	433,674	16,392	--	1,015,877	107,170	12.30
1956	2,812	3,112	892,316	65,433	492,003	222,240	476,590	7,995	775	915,159	102,864	13.49
1957	2,903	3,148	894,299	65,764	482,382	244,089	477,192	9,764	6	848,780	100,072	11.40
1958	2,731	3,057	706,785	42,279	373,765	177,082	418,720	1,861	--	787,733	86,126	10.31

1959	2,858	3,121	724,538	52,452	385,829	142,304	453,697	10,550	1	867,448	96,089	11.46
1960	3,025	3,338	725,309	62,352	395,013	109,558	414,724	68,170	12	796,403	80,082	12.95
1961	3,248	3,488	768,200	50,110	421,288	115,722	377,117	45,409	1,515	844,782	88,225	11.55
1962	3,406	3,565	797,774	53,415	458,574	128,781	424,016	32,751	123	936,053	92,154	11.63
1963	3,487	3,661	809,739	54,706	480,131	131,321	338,170	30,711	15	1,002,542	94,967	12.01
1964	3,693	4,028	865,531	64,951	521,503	107,356	323,997	24,054	35	1,095,215	96,114	13.57
1965	3,949	4,302	902,107	75,858	554,429	138,790	388,311	5,388	NA	1,228,412	111,486	14.50
1966	4,061	4,483	929,924	75,535	519,416	252,356	472,934	1,276	NA	1,291,528	114,937	14.50
1967	4,126	4,835	851,692	66,683	498,419	201,497	484,520	15,249	NA	1,134,592	103,692	13.85
1968	4,628	4,975	926,187	72,452	480,305	276,307	492,933	29,947	NA	1,225,295	112,590	13.50
1969	4,973	5,342	944,014	64,005	501,786	294,632	546,234	8,435	NA	1,256,796	114,951	14.65
1970	4,827	5,464	796,337	69,995	484,560	245,315	476,961	261	NA	1,076,784	113,199	15.32
1971	4,744	5,515	695,297	73,412	455,899	289,907	310,730	12,107	NA	1,137,664	108,185	[1]16.13
1972	5,131	5,436	574,411	66,876	433,922	474,106	231,212	3,923	NA	1,286,705	118,325	[1]17.75
1973	5,332	5,709	529,323	75,466	434,406	537,095	181,105	13,214	NA	1,364,350	117,617	[1]20.66
1974	5,609	5,781	503,658	71,246	458,476	489,461	217,768	17,293	NA	1,168,178	115,315	[1]35.95
1975	5,013	5,850	397,394	52,513	425,792	345,127	131,530	6,257	NA	839,445	75,053	[1]38.96
1976	5,362	5,690	452,554	62,192	439,543	648,174	88,101	3,187	NA	1,028,876	91,844	[1]37.01
1977	5,527	5,906	408,364	45,914	407,889	523,206	111,410	215	W	999,505	86,490	[1]34.39
1978	5,614	5,878	406,698	34,774	302,669	617,840	188,003	723	10,973	1,050,585	89,959	[1]30.97
1979	5,998	5,998	472,481	53,212	267,341	527,212	224,952	279	20,095	1,000,606	79,710	[1]37.30

NA Not available. W Withheld, Bureau of Mines not at liberty to publish.

[1] Delivered.

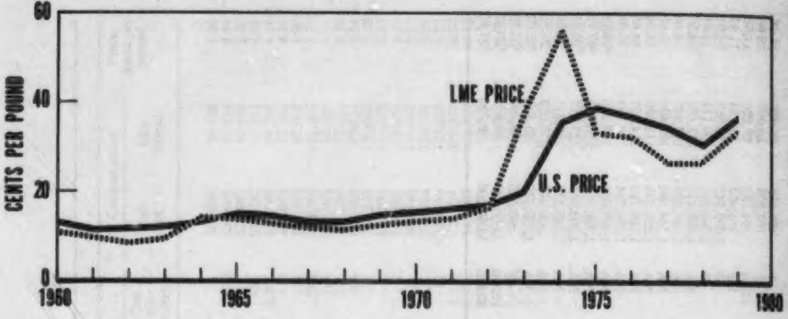

Figure 2.—Trends in average London Metal Exchange (LME) and domestic zinc prices.

DOMESTIC PRODUCTION

MINE PRODUCTION

U.S. mine production of recoverable zinc from 19 States was 302,669 tons in 1978, significantly below that of 1977, and dropped further to 267,341 tons in 1979 from 16 States. Most of the decline in production took place in Colorado, New Mexico, New York, and Utah as the result of strikes and mine closures.

The 25 leading U.S. zinc mines accounted for 95% of the recoverable domestic zinc mined in 1978 and 98% in 1979. The 10 leading mines accounted for 69% of total mine production in 1978 and 68% in 1979. Tennessee was the foremost producer of zinc during 1978-79. Eight underground mines produced zinc from zinc ores, and three underground mines and one open pit mine at the Copperhill deposit produced zinc from copper-zinc ore in 1978-79. Jersey Miniere Zinc Co., a 60-40 joint venture of The New Jersey Zinc Co. and Union Miniere, S.A. of Belgium, continued development of the Gordonsville mine and completed construction of a new 8,200-ton-per-day mill at the site. Further development of the Stonewall mine was deferred. The area along the Cincinnati Arch from central Tennessee to southern Kentucky in which the Elmwood and Gordonsville mines are being developed, continued to be the focal point for zinc exploration by a large number of foreign and domestic companies during 1978-79.

In east Tennessee, New Jersey Zinc continued construction and development at its Beaver Creek property and began production from the Lost Creek orebody which is adjacent to the Jefferson City mine. ASARCO Incorporated maintained production at the Young and Immel mines in 1978-79. The New Market and Coy mines, which had been shut down in 1977 due to poor demand for zinc concentrates, reopened in January and June 1979, respectively. Strikes in 1979 curtailed production at all four mines. The zinc concentrate produced from the Young and Immel mines is used mainly for the production of zinc oxide at ASARCO's own plants in Ohio and Illinois.

St. Joe Minerals Corp., in a joint venture with a subsidiary of Freeport Minerals Co., completed an exploration shaft and started drifting for further exploration of the ore zone at its Carthage project near Nashville, Tenn. Ore reserves were estimated at 45 to 70 million tons grading 3.5% to 5.2% zinc. Detailed drilling to further evaluate the potential of a large low-grade zinc prospect at Fountain Run, Ky. was continued by St. Joe during 1978. Drilling to 2,000 feet has indicated ore grading 2% to 4% zinc which was considered uneconomical due to the depth of the deposit and the current price of zinc. Cominco American Inc., in a joint venture with ASARCO and NL Industries, Inc., completed two exploration and ventilation shafts at the Prewitt Hollow zinc project near Burkesville, Ky.

Zinc production as a coproduct came from eight lead mines in Missouri in 1978-79. Ozark Lead Co. began expansion in 1979 of the Milliken mine, formerly the Ozark mine, which could provide an additional 2,000 tons of zinc per year when completed in 1981. Production at the Buick mine near Boss, Mo., owned 50% each by Homestake Mining Co. and AMAX Inc., declined 11% in 1978 as a result of a 10-week labor strike.

As a result of a program of planned increases begun in 1978, about 1.8 million tons of ore were milled in 1979, the highest tonnage since the mine began production. Ore reserves were given as 44 million tons grading 6.5% lead and 1.6% zinc.

In New York, at St. Joe Zinc's Balmat and Edwards mines, production in both years declined sharply as a result of a strike which began on June 1, 1978, and ended in July 1979. St. Joe had made arrangements to assure a supply of raw material to its smelter at Monaca, Pa., through 1979, as production at the mine was scheduled for half its normal rate following settlement of the differences between labor and management. The company estimated that known ore deposits at the Edwards mine will be depleted within 3 years of normal production.

In Colorado, zinc production was from eight mines in 1978 and seven mines in 1979. Idarado Mining Co., owned 80.1% by Newmont Mining Corp., placed the Idarado mine on care and maintenance status in July 1978 as a result of low zinc prices and high smelting and refining charges. In August 1978 the Camp Bird mine was closed indefinitely due to high costs and mining problems. Resurrection Mining Co., wholly owned by Newmont Mining Corp. and managed by ASARCO, mined 8% less ore in 1979 than in 1978 at the Leadville mine. Ore reserves were 1.5 million tons grading 10.1% zinc and 5% lead at yearend 1979. Homestake Mining Co. produced some byproduct zinc from its Bulldog silver mine near Creede. In June 1978 the Sunnyside gold mine of Standard Metals Corp., which produces byproduct zinc, was flooded out when the bed of an overlying lake collapsed into the present workings and those of an old stope. The mine was reopened in 1979.

Production of zinc in Idaho was reported from about 20 mines in 1978-79, but about half of them produced less than 1 ton each as a byproduct from other metal mining operations. At The Bunker Hill mine of The Bunker Hill Co., a wholly owned subsidiary of Gulf Resources & Chemical Corp., production in 1978 increased over that of 1977. Production from the Star-Morning Unit Area, owned 30% by Hecla Mining Co., decreased slightly in 1979 to 257,700 tons grading 6.4% zinc, 4.9% lead, and 96 grams of silver per ton. Ore reserves at the mine were increased to 1.4 million tons through the development of new ore and increased metal prices which lowered the cutoff grade for mining. Hecla's wholly owned Lucky Friday mine produced 159,600 tons of ore in 1979 compared with 143,900 tons mined during 1978. Ore grade was 1.5% zinc and 11.5% lead, with 562 grams of silver per ton. Calculated ore reserves at the end of 1979 were 530,000 tons. Operating costs increased about 23% in 1978 compared with about a 13% increase during 1977. Development continued on the west end of the Lucky Friday vein in 1979, and the sinking of a new shaft was expected to increase production by 35%. Intermountain Mining Engineers, with equal participation by U.S. Antimony Corp., produced zinc together with lead, silver, and gold from its recently rehabilitated Nabob mine located in the Pine Creek area of the Coeur d'Alene mining district.

In Utah, Park City Ventures, a joint venture owned 60% by The Anaconda Company and 40% by ASARCO, closed the Ontario mine in February 1978 when it became unprofitable. In 1979, Noranda Exploration Inc., a subsidiary of Noranda Mines Ltd., acquired the assets of Park City Ventures. In mid-1978, the Kennecott Copper Corp. ceased mining operations at the Burgin mine.

In Virginia, Piedmont Mineral Associates, a joint venture of Callahan Mining Corp. (49%) and New Jersey Zinc (51%), conducted cost studies on one zinc property to determine the feasibility of producing zinc chemicals, sulfuric acid, and other sulfur or metal products.

No mines produced zinc in Washington in 1979, compared with one mine in 1978, two in 1977, and four in 1976. Bunker Hill's Pend Oreille mine remained on a care and maintenance basis pending improvement in the zinc market.

In northern Maine, Superior Oil Co. and Louisiana Land and Exploration Co. continued exploration and drilling on their large zinc-copper discovery at Bald Mountain. Sulfide mineralization in two major ore types consisted of 9.1 million tons of zinc ore assaying 2.5% zinc, and 3.6 million tons of copper-zinc ore assaying 1.1% copper and 1.8% zinc. Both ore types contain some values in gold and silver. Pilot plant studies were planned for 1979-80. The Bald Mountain deposit is on land leased from the Great Northern Nekoosa Paper Co.

In Wisconsin, the Exxon Minerals Co., U.S.A., a division of Exxon Corp., continued evaluation and feasibility studies on its large zinc-copper discovery near Crandon in northern Wisconsin. Permits were sought in 1979 for underground development work. Because of depressed zinc prices, Eagle-Picher Industries, Inc., closed the Bear Hole mine at the end of February 1978 and reduced its mining activities at the Shullsburg mine until October 1, 1978, when it was closed because of unfavorable economic conditions and high costs of environmental regulations. In October 1978, Noranda Exploration Inc., closed its Rhinelander district exploration office due to low zinc prices and a new State mining tax law.

Following the 1977 closure of the Bruce mine by Cyprus Mines Corp., no zinc mines were in operation in Arizona during 1978-79. Some byproduct zinc was recovered, however, by mines engaged in producing principally silver or copper.

Bunker Hill cited poor conditions in the zinc market and in 1978 closed its Pan American zinc mine and 1,360-ton-per-day Caselton concentrator located in Lincoln County, Nev.

Near Pinos Altos, Grant County, N. Mex., close-spaced drilling by Exxon Minerals at a new base metal discovery confirmed probable reserves of about 7 million tons of ore containing 3% zinc, 2% copper, and a lesser amount of silver. Operations at the Ground Hog mine of ASARCO were shut down completely in August 1978 for economic reasons.

Houston Oil and Minerals Corp., in a joint venture with General Crude Oil Co., continued its drilling program to make a preliminary economic evaluation of lead-zinc mineralization discovered during 1977 in the Western Brooks Mountain Range of Alaska, 80 miles north of Kotzebue. Elsewhere in Alaska, Pan Sound, a joint venture of Noranda Mines Ltd., Texas Gas Transmission Corp., Mitsubishi Corp., and Marietta Resources International, announced the discovery in 1978 of silver, lead, zinc, and copper mineralization near Hawk Inlet on Admiralty Island. In the Southwestern Brooks Range, the Ambler Mining Co., a limited partnership of The Anaconda Company and Sunshine Mining Co., continued drilling and evaluation in 1978 of their silver, lead, zinc, and copper property which was discovered in 1975.

SMELTER AND REFINERY PRODUCTION

U.S. slab zinc production at seven primary plants and eight secondary plants decreased slightly in 1978 from that of the previous year, but increased substantially in 1979. During 1978-79, ASARCO's Corpus Christi, Tex. electrolytic zinc plant processed domestic and foreign zinc concentrates as well as zinc fume. A modernization program was underway in 1979 at the plant to allow treatment of a wider variety of concentrates, reduce costs, and expand capacity by 25%. Completion was expected by yearend 1981. Plans for the construction of a new zinc plant in Kentucky were terminated in 1978 due to the depressed condition of the zinc market.

Amax Zinc Co., Inc., produced more zinc in 1979 than in 1978 at its Sauget, Ill., electrolytic zinc plant. About one-third of the feed for the facility came from Amax's share of production from subsidiary companies in Missouri and one-quarter from the company's share in the Newfoundland mine in Canada. Production was suspended for 7 weeks in 1978 as a result of a coal industry strike that interrupted the supply of electrical power. Bunker Hill in Idaho produced more slab zinc in 1978 than in 1977 when production was intentionally held back because of the poor zinc market. During 1978, approximately 67% of Bunker Hill's finished zinc production was Special High Grade zinc and the remaining 33% was galvanizing grades and zinc alloys. Sales of zinc metals were handled by The Bunker Hill Sales Co. in Kellogg, Idaho.

For the fiscal year ended July 31, 1978, New Jersey Zinc showed a 16% increase in slab zinc production; capacity utilization was 85% for metal production. Company mines produced 80% of the concentrate requirements for the Palmerton Pa. plant.

Metal production began in late November 1978 at Jersey Miniere's new zinc refinery at Clarksville, Tenn. The $97 million, 82,000-ton-per-year facility is the first completely new zinc refinery to be built in the United States since 1941. Concentrate from the Tennessee mines being developed by the partnership was transported to the plant by rail or truck; however, the company eventually plans to use river barges to transport the concentrate from the mills to the smelter.

During 1978, St. Joe Zinc completed a study on the feasibility of constructing a new electrolytic plant in place of its electrothermic plant at Monaca, Pa. The company closed the plant in December 1979 because of high energy and work force requirements and the substantial capital required to meet new environmental regulations.

Secondary slab zinc was produced at four primary plants in 1979, with St. Joe Zinc being the largest producer. Of the nine companies producing slab zinc solely from secondary materials, Pacific Smelting Co. and W. J. Bullock, Inc., were the largest producers. The grade of zinc from secondary plants was all Prime Western.

Slag-Fuming Plants.—Slag-fuming plants processed lead blast furnace slags and residues to produce zinc oxide fume. The oxide was either sold and used as oxide or sent to smelters and refineries for processing into metallic zinc. Three plants operated in 1978-79; ASARCO at El Paso, Tex., and East Helena, Mont., and Bunker Hill at Kellogg, Idaho.

Byproduct Sulfuric Acid.—Production of byproduct sulfuric acid from zinc plants was 686,276 tons in 1978, and 773,836 tons in 1979. In 1978, seven plants roasted zinc sulfide concentrates and produced sulfuric acid, with one plant operating solely to produce calcine for processing to zinc oxide or slab zinc. In 1979, byproduct sulfuric acid was also produced from the new zinc plant in Tennessee.

Zinc Dust.—St. Joe Zinc constructed a zinc dust plant at Monaca, Pa., in 1978 with a capacity of 3,600 tons per year, but production ended in December 1979 with the plant's closure.

CONSUMPTION AND USES

More companies participated in the slab zinc consumption survey in 1978 and reported slab zinc consumption increased over that of 1977. A large increase in shipments of galvanized steel to the automotive industry, as reported by the American Iron and Steel Institute, contributed to higher zinc consumption. In 1979, reported slab zinc consumption for the first half of the year was 7% greater than that of the comparable 1978 period. In the second half of 1979 consumption fell compared with that of the second half of 1978 as the result of cutbacks in automobile production and the downturn in the construction industry. For 1979, most of the decline was in diecasting alloys as automobile production fell from 9.17 million units in 1978 to 8.42 million units in 1979.

Production of rolled zinc products decreased to 23,585 tons in 1978 and 21,100 tons in 1979. Strip and foil accounted for 79% of the total in 1978 and 78% in 1979. Production of rolled zinc from scrap was 19,788 tons in 1978, and 18,556 tons in 1979.

The Zinc Institute Inc., conducted a survey of over 400 diecasters in 1978-79 to determine the market distribution of zinc die castings shipped by these companies. The results showed that automotive components continued to decline and accounted for 43.3% of the total in 1979. Builders' hardware fell slightly to 22.1% and domestic appliances remained unchanged at 7.1%. Industrial, agricultural, and commercial machinery; electrical components; scientific and professional equipment; and miscellaneous uses have shown increased use of zinc die castings in recent years.

ZINC PIGMENTS AND SALTS

Production.—Production and shipments of zinc oxide in 1978-79 decreased from those of 1977. The source of domestic zinc oxide production was slightly more than half from ore and concentrate (American process), about one-quarter from slab zinc (French process), and about one-fifth from secondary material. Total French process zinc oxide, including that from remelt and scrap, was 38% of the total in 1978 and 36% in 1979. Lead-free zinc oxide was produced at 13 plants in 1978-79 and leaded zinc oxide was produced at 1 plant.

Zinc sulfate production from about a dozen companies showed a significant increase in 1978 over that of 1977, mainly because of additional reporting companies. Zinc sulfate production came from secondary material and from ore. Zinc chloride production from five companies was derived entirely from secondary material.

In its 10-K report, St. Joe Zinc showed production of 48,654 tons of zinc oxide in 1978. ASARCO, with plants at Columbus, Ohio, and Hillsboro, Ill., produced about 31,800 tons in 1978 and 30,900 tons in 1979, according to its annual report. ASARCO produced zinc oxide from concentrates produced by company mines in Tennessee and from zinc metal. New Jersey Zinc produced both American and French process zinc oxide. Other major zinc oxide producers such as the Eagle-Picher, Hillsboro, Ill., plant and the Sherwin-Williams Co., Coffeyville, Kans., plant, used calcines, fume, and secondary materials as raw materials. New Jersey Zinc and St. Joe Zinc were the two largest of the half-dozen producers of French process zinc oxide. With the closure of its Monaca plant, St. Joe Zinc ceased production of zinc oxide.

Consumption and Uses.—The apparent consumption of zinc oxide increased to about 205,000 tons in 1978 and 206,000 tons in 1979. Of the major uses of zinc oxide, only chemicals showed an increase. The use in

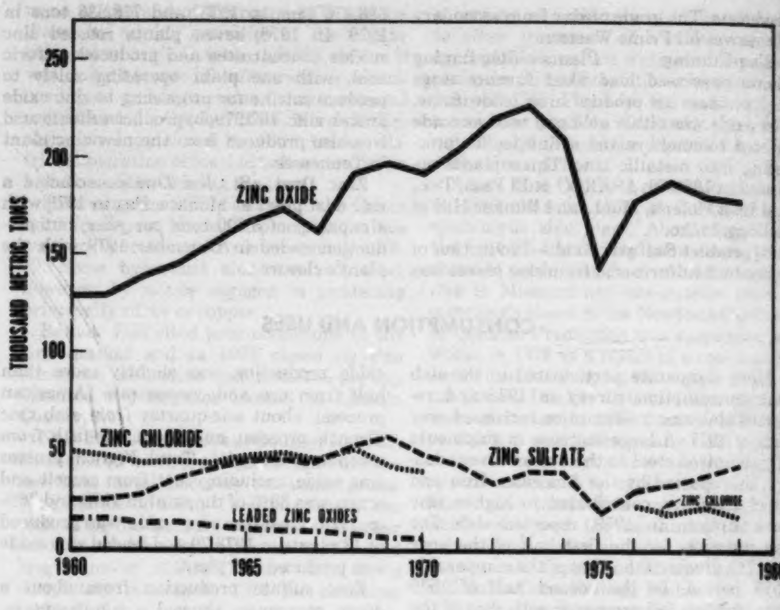

Figure 3.— Trends in shipment of zinc pigments.

photocopying continued the downward trend of recent years. Among miscellaneous uses, zinc oxide was used in floor coverings, fabrics, lubricants, plastics, and rayon manufacturing. The use of zinc sulfate in agriculture was up significantly in 1979 with lesser amounts assigned to rayon, flotation reagents, and chemicals. The use in rayon and flotation reagents declined in 1979 compared with that in 1978. Leaded zinc oxide was used in rubber, and lithopone was used mainly in paints. Shipments of zinc chloride were lower in 1979 compared with those in 1978, with most of the zinc chloride used in wood preserving, soldering, fluxes, and batteries.

Prices.—List prices for zinc oxide at the beginning of 1978 were 36.5 cents per pound for American process, lead-free pigment grade; 38 cents for French process, regular; 39.5 to 40.5 for electrophotographic grade, and 34.25 cents for 12% leaded zinc oxide. With the reduction in the price of zinc metal in February, U.S. producers lowered zinc oxide prices by 1.25 cents per pound. In June, St. Joe Zinc raised its prices 2 cents per pound for American and French process and 0.75 cent per pound for electrophotographic grade. The price of leaded zinc oxide increased from 32.9 cents to 34 cents per pound. Prices remained steady through August except for leaded zinc oxide which fell 1.5 cents to 32.5 cents per pound. Prices were raised in September through November by all producers so that by yearend prices were 40.75 cents per pound for American process zinc oxide, 42.25 cents for French process, 43.75 to 44.75 cents for electrophotographic grade, and 37 cents for 12% leaded zinc oxide.

In 1979, prices were increased by 2.25 cents in February and another 2 cents in April, but in August the price was adjusted downward by 1.5 cents and again in September by 1 cent, generally in line with movements in the price of zinc metal. In November the price was increased by 2 cents, leading to yearend prices of 44.5 cents per pound for American process, lead-free pigment grade; 46 cents for French process, regular; 47.25 to 48.25 cents for electrophotographic grade; and 39.25 cents for 12% leaded zinc oxide in 50-short-ton rail car quantities.

The price of zinc sulfate, granular monohydrate industrial, 36% zinc, bags in carload lots, advanced in mid-1978 from $24 to $26.50 in January to a quoted price of $26.50

to $29 where it remained through 1979. The price of technical-grade zinc chloride, 50% solution, in tank-car quantities, was quoted at $10 to $17.55 per 100 pounds in early January 1978 and thereafter at $10 to $15.25 through yearend 1979.

Foreign Trade.—Exports of zinc oxide decreased to 1,121 tons valued at $1.178 million in 1978, with Australia, Belgium, and Canada receiving 66% of the total. In 1979, 1,057 tons valued at $1,139 was exported with Australia, Belgium, and Venezuela receiving 70% of the total. Imports of all classes of zinc compounds increased significantly in 1978-79. Zinc oxide was a major component of imports of zinc compounds and accounted for most of the increase. Mexico and Canada supplied over 90% of the zinc oxide; other European Economic Community countries contributed most of the remainder. Venezuela and India supplied 2% of the total in 1979.

STOCKS

Producer stocks at yearend 1978 were at their lowest yearend level since 1974 when they were 36,033 tons. By December 1979 the level had increased to 55,831 tons as demand slackened. The monthly data as reported by American Bureau of Metal Statistics (ABMS) showed that producer stocks at plants and elsewhere declined continuously through October 1978 to almost half that at the end of January, but increased for the next few months. In early 1979 stocks declined as demand remained strong, but in the last half of the year producer stocks increased as demand slackened.

Inventories of slab zinc at consumer plants generally trended upward during 1978 to close at 99,325 tons. In 1979, stocks were high in the first half but as economic activity waned in the second half and inventory costs increased, stocks fell from about 94,000 tons in July to just below 80,000 tons in the final months of the year.

PRICES

ASARCO initiated a price decrease of 1.5 cents per pound of zinc, effective February 21, 1978, to 29 cents for Prime Western Grade zinc, and 29.5 cents for Special High Grade. ASARCO cited high producer stocks, poor demand, and high import levels as the reasons for the price cut. At monthend other producers were quoting the same price. In June, St. Joe Zinc raised the price for Prime Western zinc by 2 cents to 31 cents per pound. All other producers quickly followed, but National Zinc and ASARCO rescinded the increase, and at monthend prices ranged from 29 to 31 cents per pound for Prime Western and High Grade; 29.25 to 31.25 cents for Controlled Lead Grade; and 29.5 to 31.5 cents for Continuous Galvanizing and Special High Grades. In mid-July, ASARCO and National Zinc raised the price of zinc by 1.5 cents per pound for all grades. At monthend prices ranged from 30.5 to 31 cents per pound for Prime Western and High Grade; 30.75 to 31.25 cents for Controlled Lead Grade; and 31 to 31.5 cents for Continuous Galvanizing and Special High Grades. On August 15, ASARCO raised its prices of Prime Western zinc to 32.5 cents, Continuous Galvanizing Grade to 32.75 cents, and Special High Grade to 33 cents. Several producers tried to list all grades at 33 cents, thereby eliminating the premium pricing system, but by monthend all producers except Bunker Hill were on the same price schedule as ASARCO. Zinc prices increased 2 cents in October when the price of Prime Western and High Grade zinc was increased to 34.5 cents by all U.S. producers except Bunker Hill which quoted all grades at 35 cents per pound. These prices remained in effect for the rest of the year.

In January 1979, producers raised their prices by 1 cent per pound, except Bunker Hill, which raised prices 0.5 cent to 35.5 cents for all grades. Prices again increased in February and March to 39.5 cents for Prime Western and High Grade zinc, with Bunker Hill quoting 39.5 cents for all grades. In June, New Jersey Zinc raised all its grades by 2 cents per pound but a month later rescinded the increase. By yearend several price adjustments had taken place, with all producers quoting 37.5 cents for Prime Western and High Grade, 37.75 cents for Controlled Lead Grade, and 38 cents for Continuous Galvanizing and Special High Grades.

In February 1978, major European custom smelters lowered their list prices by $50, to $550 per ton (24.9 cents per pound). Producers cited weak demand and widespread discounting as the reason for the price cut. Prices were increased in April by some producers and by August the price ranged from $575 to $625. Prices were increased again in September and October by major European producers to $720 per ton. Most producers considered the price increases during 1978 a reflection of a weakened dollar rather than of increased production costs. Two increases at $40 each in early 1979 and another of $45 in May brought the price to $845. By June there were reports of discounting, as many producers felt they were losing sales to customers buying lower priced zinc on the London Metal Exchange (LME). The price was lowered to $780 in July where it remained through December.

On the LME prices fell to the 1978 low of 21 cents per pound at the end of February. In March, prices began to rise, ending the year at 32 cents per pound. Production cutbacks contributed to the price increase. By early April 1979, prices were 36 to 37 cents per pound, but then gradually declined to about 28 cents in August. By yearend prices had recovered to 34 to 36 cents.

U.S. dealer prices for Special High Grade zinc steadily increased during 1978, beginning at 28.5 to 28.8 cents per pound and ending the year at 35 cents per pound. By April 1979, the price was 39.5 to 40 cents but declined to 34 to 37 cents in December.

On February 8, 1978, the New York Commodity Exchange (Comex) began trading on its Special High Grade zinc contract. Trading was very light throughout 1979. Prices fluctuated upward in 1978 and ended at 34.5 cents per pound. Prices varied widely in 1979, from a high of 39.3 cents in April to a low of 28.6 cents in November.

In December 1978, the Council on Wage and Price Stability (COWPS) issued guidelines covering the nonferrous metals industry, and zinc producers were informally advised that their metals were excluded from price regulations. However, in February 1979, COWPS announced that zinc was not exempt from the guidelines because the producer prices did not follow closely enough those on organized exchanges.

FOREIGN TRADE

Exports of zinc ores and concentrate (zinc content) in 1979 were about double those of 1978. Prior to 1978, exports of zinc ores and concentrate were combined with those of lead and reported as gross weight.

General imports of zinc in ore and concentrates increased substantially in 1978-79 to double those of 1977.

In June 1978, the U.S. Department of the Treasury reversed an earlier decision on the Spanish zinc case by reducing the ad valorem penalty duty on imports of Spanish zinc from 4% to 1.29%. Because of intense criticism, Treasury again reversed its position in November and notified the Spanish Government that the penalty duty would be raised to 3.19%, a decision opposed by the Spanish Government. In late December, Treasury finally amended the duty to 2.64%.

New rates of duty on zinc materials were announced as a result of the Tokyo round of multilateral trade negotiations completed in 1979. Progressively lower rates will be phased in over an 8-year period beginning January 1, 1980. The new rates are as follows:

Tariff: Item	Number	Most Favored Nation (MFN)		Non-MFN
		Jan. 1, 1980	Jan. 1, 1987	Jan. 1, 1980
Ore and concentrate	602.20	0.62 cent per pound on zinc content	0.3 cent per pound on zinc content	1.67 cents per pound on zinc content.
Fume	603.50	0.62 cent per pound on zinc content	0.3 cent per pound on zinc content	1.67 cents per pound on zinc content.
Unwrought, other than alloys	626.02	1.9% ad valorem	1.5% ad valorem	1.75 cents per pound.
Alloys	626.04	19% ad valorem	19% ad valorem	45% ad valorem.
Waste and scrap	626.10	4.8% ad valorem	2.1% ad valorem	11% ad valorem.

The duty on waste and scrap remained suspended until June 30, 1981 according to P.L. 95-508. The suspension of duty on zinc ore, concentrates and other zinc bearing materials expired on June 30, 1978.

WORLD REVIEW

The World Bureau of Metal Statistics[3] indicated that world consumption of slab zinc was 6.2 million tons in 1978-79 compared with 5.9 million tons in 1977. Consumption was higher in Asia in 1979 compared with that in 1978, but consumption dropped in Europe and in Centrally Planned Economy Countries. According to the Bureau of Mines, world mine production declined in 1978 but increased in 1979 as new mines opened and became fully operational. Many mines with small production rates closed in 1978. Significant increases in primary smelter production in 1978-79 occurred in Canada, the Netherlands, India, the Republic of Korea, the United States, and Australia.

Smelter production of secondary zinc, as shown in table 42, has been separated from primary zinc production where information is available. Substantial quantities of secondary slab zinc were produced in France, the Federal Republic of Germany, Japan, the United States, and the U.S.S.R. Producer stocks worldwide decreased 52% to about 400,000 tons during 1978 but by yearend 1979 had climbed to about 480,000 tons. Consumer stocks were about 185,000 tons at yearend 1979 compared with 166,000 tons 2 years earlier.[4] LME stocks increased about 5,000 tons, ending 1978 at 69.550 tons, and in 1979 they generally declined further to 46,000 tons at yearend.

World mine capacity was estimated to be 7.92 million tons of zinc in 1978, with a small increase to about 8 million tons in 1979. Most of the expansion took place in Australia, Canada, and Spain. A new mine opened in mainland China in the Hochih area of Guangxi Province in 1979. In the first phase of operation 18,000 tons of zinc will be extracted annually in addition to tin, lead, antimony, and precious metals. It was reported that construction began on a lead-zinc mine in Uzbekistan in the U.S.S.R. in 1979. The Wheal Jane mine in the United Kingdom, which closed in early 1978, and produced a small amount of byproduct zinc, was being refurbished by Carnon Consolidated Tin Mines.

World primary zinc smelter capacity increased to about 7.24 million tons per year in 1978, and to 7.26 million tons by yearend 1979. In Italy, the Monteponi electrolytic plant with a capacity of 15,000 tons per year was closed in October 1979 as part of a reorganization of the Government controlled lead and zinc operations. This closure was more than offset by increased electrolytic capacity in Austria, India, and the Republic of Korea.

Australia.—The zinc content of the ore at the Mount Isa mine in Queensland, increased from 6% in 1977 to 6.3% in 1978. Reserves declined to 56 million tons of ore assaying 6.5% zinc. Drilling results added 1 million tons to reserves but extraction and material reappraisal resulted in a net reduction of 1 million tons from that of 1977. The company deferred development of the McArthur River lead-zinc-silver deposit in the Northern Territory due to the lack of an efficient beneficiation process for the fine-grained ore. Mount Isa and Western Selcast (Pty.) Ltd., announced plans to develop the Teutonic Bore copper-zinc deposit. Production is expected in 1981 from the deposit containing 2.3 million tons of ore grading 3.5% copper, 9.5% zinc, and 165 grams of silver per ton.

At the West Coast mines in Tasmania, EZ Industries Ltd., increased production over that of 1977 to 656,013 tons of ore grading 12.7% zinc in 1978, and maintained that rate into 1979. Reserves were increased to 8.1 million tons of ore in 1979. The company commissioned a small plant to treat the silicate ores from the Beltana mine. Aberfoyle Ltd., owned 47% by Cominco Ltd., began development of the Que River zinc-lead-silver deposit in Tasmania, with production scheduled for 1981. The ore will be milled at the Rosebery concentrator at EZ Industries, after a modernization and expansion program is completed in 1981, at a rate of about 230,000 tons per year. Ore reserves were 6.3 million tons grading 9.6% zinc and 5.2% lead. Australian Mining & Smelting Ltd., produced 11% less zinc concentrate in 1978 than in 1977 because of lower zinc demand, the need for plant repairs, and lower grade of ore mined. Production recovered in 1979 to a record high as new equipment allowed the treatment of larger quantities of lower grade ore. Cobar Mines Pty. Ltd., 100% owned by BH South Ltd., treated 518,650 tons of ore in 1978, down 7% from that of 1977, but the ore grade increased to 3%. The concentrate was smelted at Cockle Creek.

EZ Industries produced 203,650 tons of zinc from the Risdon smelter in the fiscal year ending June 30, 1979, which was the highest level recorded by the company. Increased sales to Asian countries allowed the high production rate. Combined production at the Cockle Creek smelter of Sulfide Corp. Pty. Ltd., and the Port Pirie plant of The Broken Hill Associated Smelters Pty. Ltd., increased in both 1978 and 1979 over that of 1977, with operations near capacity in 1979. Pollution control projects were completed at both plants, including a 205-meter stack at Port Pirie to control ground levels of sulfur dioxide.

The mill at the Woodlawn zinc-lead-silver-copper deposit in New South Wales, in which St. Joe Minerals, Phelps Dodge Corp., and Australian Mining & Smelting Ltd. each hold a one-third interest, was completed in December 1978 and contributed substantially to production in 1979. The mill has a capacity of 2,700 tons per day. Proven reserves at Woodlawn were estimated at 6.3 million tons assaying 14.4% zinc, 5.5% lead, 1.7% copper, and 89 grams of silver per ton at yearend 1978. The mining method is open pit and about 260 workers are employed.

Canada.—Mine output in 1979 from 29 mines was up over that of 1978. Mill capacity utilization was estimated at 83%, and the average recovery rate of zinc at the mills was 84%. Mill capacity at producing mines increased to 97,000 tons of ore per day, mainly through new mine openings and expansion.[5]

In New Brunswick, Brunswick Mining & Smelting Corp. Ltd., reinstated the planned expansion of the No. 12 mine. In 1978, the company experienced a total operating cost per ton milled of $19.36[6] at its No. 12 underground mine, and $17.84 at the No. 6 mine where mining was mostly underground. Ore mined in 1979, at 2.97 million tons, was about the same as that in 1978. Proven and probable reserves were 9.3 million tons of contained zinc at yearend 1979.

In Ontario, Mattabi Mines Ltd., increased production by 8% over that of 1978 to 945,000 tons of ore grading 6.9% zinc. Ore reserves at yearend 1979 were 3.4 million tons grading 7% zinc, including 400,000 tons from a newly discovered ore lens. The Geco Div. of Noranda treated 1.5 million tons of copper-zinc ore grading 3.2% zinc. Yearend 1979 reserves were 20.4 million tons grading 3.8% zinc. Noranda began rehabilitating the Lyon Lake mine for planned commencement of mining in July 1980. Texasgulf Inc., completed the expansion at the concentrator at Kidd Creek in 1978 with the addition of a fourth circuit which increased capacity by 1.1 million tons of ore per year. Ore milled in 1979 was 3.7 million tons compared with 3 million tons in 1978. Development work continued with completion schedul for 1981, although some ore was produce from the No. 2 mine in 1979. In Octob 1979, Noranda acquired all the shares Heath Steele Mines Ltd., which had a 75 interest in the Little River Joint Venture, 3,600-ton-per-day lead-zinc-copper mine an mill near Newcastle. Reserves at yearen 1979 were 28.1 million tons of ore gradin 1.5% lead, 4.5% zinc, and 1.1% copper.

Cominco Ltd., operated the Sullivan min in British Columbia and the Pine Poin mine in the Northwest Territories in 1978-79, but closed the HB mine in August 1978 Production of zinc concentrate from the tw mines was about the same in 1979 as i 1978. Ore grade increased from 3.3% zinc i 1978 to 3.7% in 1979 at the Sullivan mine but decreased from 5.9% to 5.5% zinc at th Pine Point mine. The modernization pro gram continued at the Sullivan mine, in cluding the completion of a waste wate treatment plant for removing metallic from mine and mill water before discharg into the local river. A project to moderniz the concentrator to improve efficiency and reduce energy costs was begun in 1979 a the Pine Point mine. The company added ore reserves in excess of production in 1979 to maintain its 10-year reserves status. Cominco acquired the remaining 25% of the outstanding shares of Arvik Mines Ltd., owner of the Polaris deposit on Little Cornwallis Island. In November 1979, Cominco announced its intention to bring the Polaris zinc-lead mine into production by 1982 at a rate of 2,000 tons of ore per day. Ore reserves were given as 23 million tons grading 14.1% zinc and 4.3% lead. Cyprus Anvil Mining Corp. announced the discovery of the Cirque deposit in British Columbia in 1979 with 18 million tons of material grading 7.9% zinc, 2.3% lead, and 49 grams of silver per ton.

In Quebec, the Matagami Div. of Noranda, which includes the Mattagami Lake, Orchan, Norita, and Radiore No. 2 mines, treated 1.3 million tons of ore grading 5.4% zinc. Ore reserves at yearend 1979 were estimated at 9.5 million tons assaying 5.7% zinc. Louvem Mining Co. Inc., ceased operations at its zinc-gold-silver mining operations in 1978. At the Manitou Div., ore was exhausted.

In Manitoba, ore production in 1979 by Hudson Bay Mining and Smelting Co., Ltd., was 2% more than that of 1978, at 1.7 million tons grading 2.9% zinc compared with 3.2% zinc in 1978. The Westarm mine was brought into production in January

1978 and the White Lake mine resumed operations. The new 3,500-ton-per-day mill adjacent to the Stall Lake mine was opened in June 1979. At the Ruttan mine, Sherritt Gordon Mines Ltd. began underground mining in early 1979 and planned to phase out open pit mining in 1980.

Noranda Mines Ltd. and MacDonald Mines Ltd. announced the reopening of the former West MacDonald mine in mid-1981 under a joint venture company, Les Mines Gallen Limited. Zinc output from the open pit mine was expected to be about 19,000 tons per year.

Zinc production in the Yukon Territory from the Faro mine of Cyprus Anvil Mining Corp. was about the same in 1978 and 1979. The concentrates were sold principally to customers in Japan and the Federal Republic of Germany. Under a 2-year contract, about 14,000 tons of zinc concentrate will be shipped to the U.S.S.R. In November 1978, the company reached an agreement to acquire the Kerr Addison and Canadian Natural Resources Ltd. properties in the Anvil district. These properties include the Grum, Vangorda, and Swim deposits with reserves of about 40 million tons containing 8% to 10% lead and zinc. Kerr Addison suspended evaluation of the Grum zinc-lead-silver deposit in 1978 because the company felt the property was uneconomical. United Keno Hill Mines Ltd. produced less zinc in 1978 than in 1977 because of high treatment and transportation charges.

Production at ASARCO's Buchans mine in Newfoundland, originally scheduled to close in 1978, continued into 1979 due to higher lead and zinc prices.

In Nova Scotia, Imperial Oil Ltd. began production at Gays River in late 1979. Capacity of the mill is 1,350 tons per day. Reserves were given as 11 million tons containing 4.2% zinc and 2.8% lead.

In British Columbia, Western Mines Ltd. milled 266,877 tons of ore in 1979, about the same as that in 1978, from the Lynx and Myra mines. About 150,000 tons of new ore reserves were found, bringing the total to 1.15 million tons grading 8% zinc. The company continued exploration of the Great Slave Reef and West Reef properties in the Northwest Territories but found the deposit uneconomical at current metal prices.

Texasgulf Canada Ltd. produced 106,700 tons of zinc metal at its smelter in Ontario, up from 72,850 tons in 1978. Cominco Ltd. produced about 208,000 tons of metal, up 6% over that of 1978, at Trail, British Columbia. The company began construction for modernization and expansion of its electrolytic plant, including the first commercial-scale zinc concentrate leach plant using the pressure leaching system developed with Sherritt Gordon. Canadian Electrolytic Zinc operated its Valleyfield, Quebec smelter at 92% of capacity in 1979 compared with 73% in 1978. Canadian zinc metal capacity was 644,000 tons, which incorporated a revised figure of 218,000 tons for Valleyfield.

Canadian zinc reserves on January 1, 1979, were given as 26.5 million tons at the producing mines and deposits under development, with the Provinces of New Brunswick and Ontario containing about three-fifths of the total.

Fers et Metaux Recycles Ltd. began operations of Canada's first heavy media separation metal recycling plant in 1978. The company recovers about 5,500 tons per year of zinc die cast, mainly from shredded automobiles, and sells it for the manufacture of zinc dust, zinc oxides, and copper alloys.

Honduras.—Reserves in all ore bodies of the El Mochito mine of Rosario Resources Corp. were 7.2 million tons averaging 9.5% zinc and 4.5% lead. Ore reserves increased as a result of development work in the San Juan orebody. The mill was being expanded from 1,100 tons to 2,200 tons of ore per day.

Ireland.—Tara Mines Ltd. treated a total of 1.6 million tons of ore grading 11.4% zinc and 2.5% lead from the Navan mine in 1979, 19% above that of 1978. In 1978 a 5-week strike and modifications in mining plans cut production. Production has not reached design capacity of 2.2 million tons because of mechanical and labor problems. New Jersey Zinc withdrew from the zinc smelter project in 1978, but there were reports of Soviet and Japanese interest in building a plant at the Balylongford site.

Irish Base Metals, a subsidiary of Northgate Exploration Ltd., treated 231,404 tons of ore from the Tynagh mine, County Galway, in 1978. Production was down from that of 1977 because of a labor strike from June through December. The ore grade was 3.4% zinc and 4.1% lead, with some silver and copper. Metallurgical recovery of zinc was 79% compared with 81% in 1977. Ore reserves were given as 820,000 tons assaying 5% lead, 3.4% zinc, 0.2% copper, and 87.7 grams of silver per ton. About 295,000 tons of material was excluded from reserve estimates given in 1977 following redesign of the mining blocks. Arrangements were made for the sale of concentrates through 1980. An intensive diamond drilling program in the Tynagh area continued through 1979.

Mogul of Ireland Ltd. mined 610,856 tons of ore grading 5.6% zinc and 3.2% lead, 7% less than in 1978. Metal recovery of zinc was 83% and operating costs increased 20% over those of 1978. Ore reserves after dilution were 3.1 million tons grading 5.2% zinc and 2.6% lead.

Japan.—The stockpile program, initiated in 1976 by the Metallic Minerals Stockpile Association, held a total of 160,270 tons by yearend 1978, made up of 21,000 tons in the Government stockpile and 139,720 tons in the private stockpile.

Dowa Mining Co. Ltd. began operations at the Ezuri mine in 1979. Production was expected to be 14,000 tons of zinc and 4,000 tons of lead annually by 1980. Reserves were given as 3 million tons of ore grading 14% zinc and 8% lead, with lesser quantities of copper, gold, and silver.

Several mines with an annual production of about 4,000 tons of zinc closed during 1978 because of high production costs and low zinc prices. Mitsui Mining & Smelting Co., Ltd., curtailed production at its Kamioka mine several times in 1978 to reduce its stock of zinc concentrate. Mine capacity is 6,500 tons of ore per day. Mitsui also closed its Hikoshima zinc plant, with an annual capacity of 84,000 tons, during August 1978.

Mexico.—Industrial Minera Mexico, S.A. (IMM), was restructured to comply with Mexican law resulting in ASARCO's 34% ownership now in Mexico Desarrollo Industrial Minero, S.A., a new holding company for IMM. IMM opened the new Tecolote copper-zinc-tungsten mine in 1978 with a capacity of 9,000 tons of zinc per year. Expansion projects were underway at Taxco, Santa Barbara, and San Martin, increasing capacity from 6,100 tons of ore per day to 12,200 tons. IMM began construction of the Rosario silver-lead-zinc mine with a capacity of 730 tons of ore per day, and the Velardena silver-lead-zinc mine is expected to start up in early 1980 at a rate of 800 tons per day.

Nicaragua.—Neptune Mining Co., owned 52.5% by ASARCO, placed the Vesubio mine on standby in August 1978 for economic reasons. In November 1979, the Government issued a decree nationalizing the mining industry in that country, including the mines owned by Neptune.

Peru.—Zinc mine production in 1978 was below that of 1977 because of labor strikes in midyear. Centromin, the State mining company, accounted for 42% of the country's production in 1978-79. Cia. Minera Milpo S.A., one of the most important lead-zinc producers in the medium sector, completed a new 1,800-ton-per-day concentrator in 1979. The mill, which replaces an older unit, will increase capacity by 13,000 tons of zinc per year. San Ignacio de Morococha S.A., Peru's second largest producer with 32,960 tons in 1979, continued with its mine expansion of 33% to 2,000 tons of ore per day. Cia. Minera Atachocha, S.A., which produced 17,100 tons of zinc in 1979, increased its plant capacity 20% in 1979 to 1,800 tons of ore per day. In 1978, the Government exempted mining companies producing zinc as their principal product from the 17.5% export tax, a step which aided zinc producers in a market of low international prices.

Basic engineering work continued and construction began on the 100,000-ton-per-year zinc refinery to be built at Cajamarquilla.

Cia. Minera del Madrigal, a division of Homestake Mining, continued to mine copper-lead-zinc ore. ASARCO, through Northern Peru Mining Corp., produced 7,300 tons of zinc from the Quiruvilca mine in 1978 and 8,250 tons in 1979. New orebodies were discovered with high silver content, and a 30% expansion was planned. Cia Minerales Santander, Inc., a subsidiary of St. Joe Minerals, produced about 73,000 tons of zinc concentrates in 1978-79, a substantial increase over that of 1977. Work began on a new tunnel to gain access to new mineralization at lower levels.

South Africa, Republic of.—Black Mountain Mineral Development Co. Ltd., of which Phelps Dodge Corp. owns 49%, began trial milling in late 1979 at the Broken Hill mine at Aggeneys. Beginning in 1980, the annual production from the mine was expected to be about 90,000 tons of lead, 18,000 tons of zinc, and a byproduct copper and silver. Proven reserves amount to 38 million tons grading 6.4% lead, 2.9% zinc, and lesser quantities of copper and silver.

Spain.—The Rubiales zinc-lead mine of Exploracion Minera International Espana, S.A., in which Cominco Europe NV is the major shareholder with 47.48%, began commercial operation on July 1, 1978. Ore production in 1979 was 680,000 tons grading 8.9% zinc and 2% lead. Reserves at yearend 1979 were 12.5 million tons of ore grading 7.6% zinc and 1.4% lead. The entire output has been contracted for sale to smelters in

Spain under long-term sales agreements. Andaluza de Piritas began production at its open pit mine and mill at Aznalcollar in 1979 at the rate of 57,000 tons of contained zinc per year.

Thailand.—In August 1978, Gulf & Western Industries sold its 55% holding of Thai Zinc Ltd., which held a concession for the Mae Sot zinc deposit, to Whashin Industrial Co., a South Korean firm. It was reported that Whashin arranged financing for the mine and smelter project in late 1979.

Yugoslavia.—Work was under way at the Trepca mine to expand production by 14,000 tons of contained zinc by 1980, and at the Srebrenica mine by 7,000 tons. Expansion started at the Kopaonik lead and zinc mill at Leposanic, Serbia, and should be completed in 1980.

TECHNOLOGY

At the Rolla (Mo.) Research Center of the Bureau of Mines researchers evaluated solvent extraction and precipitation techniques to remove and recover cobalt and nickel from zinc sulfate solution prior to electrolysis. Several reagents lowered the cobalt and nickel levels to less than 0.1 part per million.[7] In another investigation a technique was developed to produce zinc sulfate and elemental sulfur from sphalerite concentrates by reaction with sulfuric acid at 175° to 200°C and ambient pressure.[8] More than 98% of the zinc was recovered. Advantages cited for the method over conventional pyrometallurgical processes were elimination of sulfur dioxide gas, production of a solid sulfur product, and higher zinc recoveries due to elimination of zinc ferrite losses. Laboratory procedures were developed for converting galvanizing wastes to zinc oxide containing less than 0.25% lead. The product is suitable for metallurgical and chemical uses.[9] An inexpensive method was developed that allows the use of zinc cathodes in place of aluminum cathodes in the electrolytic process and makes possible the use of electrolyte containing high amounts of soluble fluoride.[10]

At the Bureau's Salt Lake City (Utah) Research Center an improved method was developed for removing selenium from zinc smelter gas scrubber effluent. Zinc powder was used and treatment costs appeared to be low.[11] At the Albany (Oreg.) Research Center the standard Gibbs energy, enthalpy, and entropy of formation of sphalerite were determined.[12]

At the Bureau's Reno (Nev.) Research Center a detailed investigation was conducted on the fused salt electrolysis of zinc chloride to produce zinc metal.[13]

Work was conducted at the Intermountain Field Operations Center to determine the derivation of minor metal byproducts from lead and zinc production plants.[14]

Under a Bureau of Mines contract, Arthur D. Little, Inc., conducted a study on the recycling of mineral material, including zinc. An energy analysis was presented for scrap preparation, zinc dust production, slab zinc production, pot melting of clean die-cast scrap and off-specification die-cast scrap.[15] A coal mine slump refuse deposit in west-central Illinois was found to contain about 900,000 metric tons of coal and 1,000 metric tons of zinc. Batch tests demonstrated the feasibility of producing both coal and zinc-rich concentrates using a spiral concentrator.[16]

Treatment of a wide range of zinc concentrate grades was demonstrated in a zinc pressure leach process using sulfuric acid with extractions of zinc as high as 99%. The process offers economic advantages in addition to the formation of elemental sulfur rather than sulfur dioxide.[17]

A study on the economic impact of environmental regulations was sponsored by 10 companies involved in the production of copper, lead, and zinc. The results showed that compliance with the regulations would increase the cost of zinc production by about 10%.[18]

A new separator for the electrodes in nickel-zinc batteries was developed which could lead to economical electric cars in 3 to 5 years. The energy density of the nickel-zinc battery is almost twice that of existing lead-acid batteries so that the car could travel about 100 miles on a single charge.[19]

An analysis was carried out of the energy consumption of the zinc-lead blast furnace process which is currently in use in 11 countries. It was found that the process is more economical in the use of primary fossil-fuel energy to make Special High Grade zinc than is the electrolytic zinc process, and for less-refined zinc grades, the advantages are greater.[20]

A method was developed for recovering metals from dilute solutions using a fluidized bed of glass beads in combination with screenlike expanded-mesh electrodes. Possible applications include recovery of metals such as zinc from electroplating effluents and from dilute streams such as mine discharges.[21]

The New Jersey Zinc Co. patented a complex zinc oxide product which could find application as a scrubber of sulfur dioxide from weak flue gases. The saturated material would be returned to a zinc smelter for recovery of both the zinc and sulfur.[22]

A solvent extraction process was commercialized which has potential applications in recovering zinc from oxide ores and low-grade secondary sources.[23]

A comprehensive coverage of zinc-related investigations and an extensive review of current world literature on the uses of zinc and its products are contained in quarterly issues of Zinc Abstracts published by the Zinc Development Association, London, W1X 6AJ England.

Progress reports of the projects supported by the International Lead and Zinc Research Organization, Inc. (ILZRO), are released annually in the ILZRO Research Digest.

Table 3.—Mine production of recoverable zinc in the United States, by State

(Metric tons)

State	1975	1976	1977	1978	1979
Arizona	7,852	8,619	3,978	W	W
California	187	154	2	W	W
Colorado	43,962	45,923	36,530	22,208	9,910
Idaho	37,127	42,262	28,121	32,353	29,660
Illinois	W	W	W	W	W
Kentucky	37	54	--	52	--
Maine	7,546	7,065	6,594	--	--
Missouri	67,918	75,777	74,107	59,038	61,682
Montana	100	58	72	79	104
Nevada	4,986	1,305	1,517	1,371	W
New Jersey	28,218	30,633	30,358	28,915	31,118
New Mexico	9,998	W	W	W	W
New York	69,501	66,833	64,264	26,463	12,133
Pennsylvania	19,133	20,212	20,706	19,099	21,447
Tennessee	75,562	74,854	82,044	87,906	85,119
Utah	17,817	20,394	16,111	3,509	W
Virginia	13,745	10,198	12,040	10,974	11,406
Washington	W	W	5,055	W	--
Wisconsin	W	W	W	W	W
Other States	22,108	35,182	26,395	10,703	4,762
Total	425,792	439,543	407,889	[1]302,669	267,341

W Withheld to avoid disclosing company proprietary data, included with "Other States."

[1] Data do not add to total shown because of independent rounding.

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[1] Physical scientist, Section of Nonferrous Metals.

[2] Statistical specialist, Section of Nonferrous Metals.

[3] World Bureau of Metal Statistics (London). World Metal Statistics. V. 33, No. 5, May 1980, p. 101.

[4] International Lead and Zinc Study Group. Lead and Zinc Statistics. Monthly Bull., v. 20, No. 6, June 1980, p. 37.

[5] Canadian Mineral Survey 1980. Preprint from Can. Min. J., February 1980. 90 pp.

[6] Where necessary, 1978 values have been converted from Canadian dollars (Can$) to U.S. dollars at the rate of Can$1.14=US$1.00.

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Table 4.—Mine production of recoverable zinc in the United States, by month

(Metric tons)

Month	1978	1979
January	30,357	23,259
February	29,813	21,655
March	31,629	23,798
April	31,588	21,120
May	29,692	22,991
June	20,339	21,921
July	17,857	20,853
August	23,008	25,397
September	22,065	18,715
October	23,668	23,793
November	21,248	22,189
December	21,460	21,655
Total	302,669	267,341

Table 5.—Production of zinc and lead in the United States in 1978, by State and class of ore, from old tailings, etc., in terms of recoverable metals

(Metric tons)

State	Zinc ore			Lead ore			Zinc-lead ore		
	Gross weight (dry basis)	Zinc content	Lead content	Gross weight (dry basis)	Zinc content	Lead content	Gross weight (dry basis)	Zinc content	Lead content
Arizona	--	--	--	(1)	--	(1)	--	--	--
Colorado	--	--	--	(1)	--	(1)	283,338	14,266	8,388
Idaho	(1)	(1)	(1)	(1)	(1)	(1)	789,278	30,228	29,081
Missouri	--	--	--	7,962,153	59,038	461,762	--	--	--
Montana	--	--	--	--	--	--	(1)	(1)	(1)
Nevada	--	--	--	--	--	--	(1)	(1)	(1)
New Jersey	167,074	28,915	--	--	--	--	--	--	--
New York	392,959	26,463	990	--	--	--	--	--	--
Pennsylvania	448,736	19,099	--	--	--	--	--	--	--
Tennessee	3,291,988	83,968	--	--	--	--	--	--	--
Utah	--	--	--	(1)	(1)	(1)	93,370	3,496	2,435
Virginia	455,414	10,974	1,803	--	--	--	--	--	--
Other States[2]	155,102	3,228	223	42,747	4,893	805	--	--	--
Total	4,911,273	172,647	3,016	8,004,900	63,931	462,567	1,165,986	47,990	39,904
Percent of total zinc-lead	--	57	1	--	21	87	--	16	7

State	Copper-zinc, copper-lead, and copper-zinc-lead ores			All other sources[3]			Total		
	Gross weight (dry basis)	Zinc content	Lead content	Gross weight (dry basis)	Zinc content	Lead content	Gross weight (dry basis)	Zinc content	Lead content
Arizona	--	--	--	[1] 44,583,434	W	[1] 416	44,583,434	W	416
Colorado	180,212	7,125	4,270	[1] 202,437	817	[1] 2,493	665,987	22,208	15,151
Idaho	--	--	--	[1] 723,690	[1] 2,125	[1] 15,680	1,512,968	32,353	44,761
Missouri	--	--	--	--	--	--	7,962,153	59,038	461,762
Montana	--	--	--	[1] 8,409	[1] 79	[1] 132	8,409	79	132
Nevada	--	--	--	[1] 787,727	[1] 1,371	[1] 653	787,727	1,371	653
New Jersey	--	--	--	--	--	--	167,074	28,915	--
New York	--	--	--	--	--	--	392,959	26,463	990
Pennsylvania	--	--	--	--	--	--	448,736	19,099	--
Tennessee	1,837,426	3,938	--	--	--	--	5,129,414	87,906	--
Utah	--	--	--	[1] 4,990	[1] 13	[1] 106	98,360	3,509	2,541
Virginia	--	--	--	--	--	--	455,414	10,974	1,803
Other States[2]	--	--	--	600,132	2,634	424	797,981	10,755	1,452
Total[4]	2,017,638	11,063	4,270	46,910,819	7,039	19,904	63,010,616	[4]302,669	529,661
Percent of total zinc-lead	--	4	1	--	2	4	--	100	100

W Withheld to avoid disclosing company proprietary data; included in "Other States."

[1] Zinc ore, lead ore, zinc-lead ore and ore from "all other sources" combined to avoid disclosing company proprietary data.

[2] Other States include Alaska, California, Illinois, Kentucky, New Mexico, Texas, Washington, and Wisconsin.

[3] Zinc and lead recovered from copper, gold, silver, and fluorspar ores, and from mill tailings and miscellaneous cleanups.

[4] Data may not add to totals shown because of independent rounding.

Table 6.—Production of zinc and lead in the United States in 1979, by State and class of ore, from old tailings, etc., in terms of recoverable metals

(Metric tons)

State	Zinc ore			Lead ore			Zinc-lead ore		
	Gross weight (dry basis)	Zinc content	Lead content	Gross weight (dry basis)	Zinc content	Lead content	Gross weight (dry basis)	Zinc content	Lead content
Arizona	--	--	--	510	([1])	28	--	--	--
Colorado	([1])	([1])	--	([1])	--	--	163,507	8,870	5,707
Idaho	--	--	--	660	19	121	750,999	27,500	24,607
Missouri	--	--	--	8,262,993	61,682	472,054	--	--	--
Montana	--	--	--	11,688	50	173	([1])	([1])	([1])
Nevada	--	--	--	--	--	--	--	--	--
New Jersey	175,694	31,118	--	--	--	--	--	--	--
New York	144,232	12,133	458	--	--	--	--	--	--
Pennsylvania	477,726	21,447	--	--	--	--	--	--	--
Tennessee	3,256,310	81,358	--	--	--	--	--	--	--
Virginia	445,096	11,406	1,596	--	--	--	--	--	--
Other States[2]	--	--	--	([1])	([1])	([1])	--	--	--
Total	4,499,058	157,462	2,054	8,275,851	61,751	472,376	914,506	36,370	30,314
Percent of total zinc-lead	--	59	--	--	23	90	--	14	6

State	Copper-zinc, copper-lead, and copper-zinc-lead ores			All other sources[3]			Total		
	Gross weight (dry basis)	Zinc content	Lead content	Gross weight (dry basis)	Zinc content	Lead content	Gross weight (dry basis)	Zinc content	Lead content
Arizona	--	--	--	[1] 47,433,240	W	[1] 326	47,433,750	W	354
Colorado	--	--	--	[1] 192,336	[1] 1,040	1,847	355,843	9,910	7,554
Idaho	--	--	--	703,675	2,141	17,908	1,455,334	29,660	42,636
Missouri	--	--	--	--	--	--	8,262,993	61,682	472,054
Montana	--	--	--	[1] 6,402	[1] 54	[1] 85	18,090	104	258
Nevada	--	--	--	41,188	--	24	41,188	--	24
New Jersey	--	--	--	--	--	--	175,694	31,118	--
New York	--	--	--	--	--	--	144,232	12,133	458
Pennsylvania	--	--	--	--	--	--	477,726	21,447	--
Tennessee	1,900,925	3,761	--	--	--	--	5,157,235	85,119	--
Virginia	--	--	--	--	--	--	445,096	11,406	1,596
Other States[2]	--	--	--	[1] 2,060,238	[1] 4,762	[1] 635	2,060,238	4,762	635
Total	1,900,925	3,761	--	50,437,079	7,997	20,825	66,027,419	267,341	525,569
Percent of total zinc-lead	--	1	--	--	3	4	--	100	100

W Withheld to avoid disclosing company proprietary data; included in "Other States."

[1] Zinc ore, lead ore, zinc-lead ore and ore from "all other sources" combined to avoid disclosing company proprietary data.

[2] Other States include California, Illinois, New Mexico, Oregon, Utah, Washington, and Wisconsin.

[3] Zinc and lead recovered from copper, gold, silver, and fluorspar ores, and from mill tailings and miscellaneous cleanups.

Table 7.—Twenty-five leading zinc-producing mines in the United States in 1978 in order of output

Rank	Mine	County and State	Operator	Source of zinc
1	Buick	Iron, Mo	Amax Lead Co. of Missouri	Lead ore.
2	Sterling	Sussex, N.J	The New Jersey Zinc Co	Zinc Ore.
3	Balmat	St. Lawrence, N.Y	St. Joe Zinc Co	Do.
4	Friedensville	Lehigh, Pa	The New Jersey Zinc Co	Do.
5	Young	Jefferson, Tenn	ASARCO Incorporated	Do.
6	Elmwood	Smith, Tenn	The New Jersey Zinc Co	Do.
7	Zinc Mine Works	Jefferson, Tenn	United States Steel Corp	Do.
8	Star Unit	Shoshone, Idaho	The Bunker Hill Co. and Hecla Mining Co.	Lead, lead-zinc ore.
9	Bunker Hill	do	The Bunker Hill Co	Lead-zinc ore.
10	Immel	Knox, Tenn	ASARCO Incorporated	Zinc Ore.
11	Magmont	Iron, Mo	Cominco American Inc	Lead ore.
12	Leadville	Lake, Colo	ASARCO Incorporated	Lead-zinc ore.
13	Austinville and Ivanhoe.	Wythe, Va	The New Jersey Zinc Co	Zinc Ore.
14	Idol	Grainger, Tenn	do	Do.
15	Jefferson City	Jefferson, Tenn	do	Do.
16	Idarado	Ouray and San Miguel, Colo	Idarado Mining Co	Copper-lead-zinc ore.
17	Ozark	Reynolds, Mo.	Ozark Lead Co	Lead ore.
18	Ground Hog	Grant, N. Mex	ASARCO Incorporated	Zinc ore.
19	Brushy Creek	Reynolds, Mo.	St. Joe Lead Co	Lead ore.
20	Copperhill Plant	Polk, Tenn	Cities Service Co.	Copper-zinc ore.
21	Sunnyside	San Juan, Colo.	Standard Metals Corp.	Lead-zinc ore.
22	Edwards	St. Lawrence, N.Y	St. Joe Zinc Co	Zinc ore.
23	Shullsburg	La Fayette, Wis	Eagle-Picher Industries Inc.	Do.
24	Viburnum No. 29	Washington, Mo	St. Joe Lead Co	Lead ore.
25	Burgin	Utah, Utah	Kennecott Copper Corp	Lead-zinc ore.

Table 8.—Twenty-five leading zinc-producing mines in the United States in 1979 in order of output

Rank	Mine	County and State	Operator	Source of Zinc
1	Buick	Iron, Mo	AMAX Lead Co. of Missouri	Lead ore.
2	Sterling	Sussex, N.J	The New Jersey Zinc Co	Zinc ore.
3	Freidensville	Lehigh, Penn.	do	Do.
4	Elmwood	Smith, Tenn	do	Do.
5	Star Unit Area.	Shoshone, Idaho	The Bunker Hill Co. and Hecla Mining Co	Lead-zinc ore.
6	Zinc Mine Works	Jefferson, Tenn	United States Steel Corp	Zinc ore.
7	Bunker Hill	Shoshone, Idaho	The Bunker Hill Co	Lead-zinc ore.
8	Austinville and Ivanhoe.	Wythe, Va	The New Jersey Zinc Co	Zinc ore.
9	Young	Jefferson, Tenn	ASARCO Inc	Do.
10	Magmont	Iron, Mo	Cominco American Inc	Lead ore.
11	Balmat	St. Lawrence, N.Y.	St. Joe Zinc Co	Zinc ore.
12	New Market	Jefferson, Tenn	ASARCO Inc	Do.
13	Immel	Knox, Tenn.	do	Do.
14	Jefferson City	Jefferson, Tenn	The New Jersey Zinc Co	Do.
15	Leadville	Lake, Colo	ASARCO Inc	Lead-zinc ore.
16	Idol	Grainger, Tenn	The New Jersey Zinc Co	Zinc ore.
17	Brushy Creek	Reynolds, Mo	St. Joe Lead Co	Lead ore.
18	Copperhill Plant.	Polk, Tenn	Cities Services Co.	Copper-zinc ore.
19	Milliken (formerly Ozark)	Reynolds, Mo	Ozark Lead Co	Lead ore.
20	Viburnum No. 29	Washington, Mo	St. Joe Lead Co	Do.
21	Viburnum No. 28	Iron, Mo	do	Do.
22	Fletcher	Reynolds, Mo	do	Do.
23	Shullsburg	La Fayette, Wis	Eagle-Picher Industries Inc	Zinc ore.
24	Lucky Friday	Shoshone, Idaho	Hecla Mining Co	Silver ore.
25	Edwards	St. Lawrence, N.Y.	St. Joe Zinc Co	Zinc ore.

Table 9.—Primary and redistilled secondary slab zinc produced in the United States[1]

(Metric tons)

	1975	1976	1977	1978	1979
Primary:					
From domestic ores	279,376	346,429	322,208	267,350	255,344
From foreign ores	118,018	106,125	86,156	139,348	217,137
Total	397,394	452,554	408,364	406,698	472,481
Redistilled secondary	52,513	62,192	45,914	34,774	53,212
Total (excludes zinc recovered by remelting)	449,907	514,746	454,278	441,472	525,693

[1] Excludes processed zinc from the General Services Administration (GSA).

Table 10.—Distilled and electrolytic zinc, primary and secondary, produced in the United States, by method of reduction

(Metric tons)

Method of reduction	1975	1976	1977	1978	1979
Electrolytic primary	210,521	233,713	213,769	231,225	296,320
Distilled	186,873	218,841	194,596	175,473	176,161
Redistilled secondary:					
At primary smelters	31,689	34,132	26,448	24,085	40,343
At secondary smelters	20,824	28,060	19,465	10,689	12,869
Total	449,907	514,746	454,278	441,472	525,693

Table 11.—Distilled and electrolytic zinc, primary and secondary, produced in the United States, by grade

(Metric tons)

Grade	1975	1976	1977	1978	1979
Special High	219,655	212,437	151,214	179,812	173,082
High	17,158	28,466	38,494	32,830	39,247
Intermediate	7,793	9,515	8,332	--	--
Prime Western	205,301	264,328	256,238	[1]228,830	[1]313,364
Total	449,907	514,746	454,278	441,472	525,693

[1] Includes Controlled Lead Grade and Continuous Galvanizing Grade. Bureau of Mines not at liberty to publish separately.

Table 12.—Production of primary slab zinc in the United States, by State

(Metric tons)

State	1975	1976	1977	1978	1979
Idaho	83,733	91,348	54,954	76,175	73,868
Illinois	50,201	61,876	58,399	55,277	58,315
Oklahoma	31,816	20,323	40,096	42,414	43,590
Pennsylvania	138,146	198,518	194,596	175,473	176,161
Tennessee	--	--	--	1,661	69,440
Texas	93,497	80,489	60,319	55,698	51,107
Total	397,393	452,554	408,364	406,698	472,481

Table 13.—Annual slab zinc capacity of primary zinc plants in the United States

Type of plant	Plant location	Slab zinc capacity (metric tons)	
		1978	1979
Electrolytic plants:			
Amax Zinc Co., Inc	Sauget, Ill	76,000	76,000
ASARCO Incorporated	Corpus Christi, Tex	98,000	98,000
The Bunker Hill Co	Kellogg, Idaho	99,000	108,000
Jersey Miniere Zinc Co	Clarksville, Tenn	82,000	82,000
National Zinc Co	Bartlesville, Okla	51,000	51,000
Vertical-retort plants:			
The New Jersey Zinc Co	Palmerton, Pa	109,000	109,000
St. Joe Zinc Co	Monaca, Pa	201,000	201,000

Table 14.—Secondary slab zinc plants, by group capacity, in the United States

(Metric tons)

Company	Plant location	Capacity[1]	
		1978	1979
Arco Alloys Corp	Detroit, Mich	52,000	51,000
Belmont Smelting & Refining Works	Brooklyn, N.Y		
W. J. Bullock, Inc.	Fairfield, Ala		
T. L. Diamond & Co., Inc	Spelter, W. Va		
Illinois Smelting & Refining Co	Chicago, Ill		
New England Smelting Works, Inc	West Springfield, Mass		
Pacific Smelting Co	Torrance, Calif		
S-G Metals Industries Inc	Kansas City, Kans		

[1] Includes capacity at Hugo Neu-Proler Co., Terminal Island, Calif., Proler International Corp., Houston, Tex., and Prolerized Schiabo Neu Co., Jersey City, N.J., which did not produce slab zinc in 1978-79.

Table 15.—Stocks and consumption of new and old zinc scrap in the United States in 1978

(Metric tons, zinc content)

Class of consumer and type of scrap	Stocks Jan. 1[1]	Receipts	Consumption			Stocks Dec. 31
			New scrap	Old scrap	Total	
Smelters and distillers:						
New clippings	228	1,298	1,414	--	1,414	112
Old zinc	924	10,646	--	10,603	10,603	967
Remelt zinc	363	2,466	--	2645	2,645	184
Engravers' plates	133	907	--	972	972	68
Rod and die scrap	399	2,303	--	2,504	2,504	198
Diecastings	1,141	10,980	--	10,818	10,818	1,253
Fragmentized diecastings	271	18,706	--	16,500	16,500	2,477
Remelt die-cast slab	391	11,686	--	9,628	9,628	2,449
Skimmings and ashes	11,253	35,563	35,172	--	35,172	11,644
Sal skimmings	42	560	568	--	568	34
Die-cast skimmings	2,441	5,336	5,135	--	5,135	2,642
Galvanizers' dross	23,378	49,668	41,752	--	41,752	31,294
Flue dust	521	11,213	10,926	--	10,926	808
Chemical residues	--	2,609	2,609	--	2,609	--
Other	--	843	843	--	843	--
Total	41,485	164,734	98,419	53,670	152,089	54,130
Chemical plant, foundries, and other manufacturers:						
Old zinc	10	23	--	23	23	10
Rod and die scrap	18	102	--	112	112	8
Diecastings	24	107	--	114	114	17
Skimmings and ashes	3,239	5,144	5,063	--	5,063	3,320
Sal skimmings	1,686	3,842	3,790	--	3,790	1,738
Die-cast skimmings	425	363	363	--	363	425
Galvanizers dross	--	715	690	--	690	25
Flue dust	375	5,316	5,307	--	5,307	384
Chemical residues	5,187	6,716	8,031	--	8,031	3,872
Other	453	5,597	5,596	--	5,596	454
Total	11,417	27,925	28,840	249	29,089	10,253
All classes of consumers:						
New clippings	228	1,298	1,414	--	1,414	112
Old zinc	934	10,669	--	10,626	10,626	977
Remelt zinc	363	2,466	--	2,645	2,645	184
Engravers' plates	133	907	--	972	972	68
Rod and die scrap	417	2,405	--	2,616	2,616	206
Diecastings	1,165	11,037	--	10,932	10,932	1,270
Fragmentized diecastings	271	18,706	--	16,500	16,500	2,477
Remelt die-cast slab	391	11,686	--	9,628	9,628	2,449
Skimmings and ashes	14,492	40,707	40,235	--	40,235	14,964
Sal skimmings	1,728	4,402	4,358	--	4,358	1,772
Die-cast skimmings	2,866	5,699	5,498	--	5,498	3,067
Galvanizers' dross	23,378	50,383	42,442	--	42,442	31,319
Flue dust	896	16,529	16,233	--	16,233	1,192
Chemical residues	5,187	9,325	10,640	--	10,640	3,872
Other	453	6,440	6,439	--	6,439	454
Total	52,902	192,659	127,259	53,919	181,178	64,383

[1] Figures partly revised.

Table 16.—Stocks and consumption of new and old zinc scrap in the United States in 1979

(Metric tons, zinc content)

Class of consumer and type of scrap	Stocks Jan. 1[1]	Receipts	Consumption			Stocks Dec. 31
			New scrap	Old scrap	Total	
Smelters and distillers:						
New clippings	112	693	770		770	35
Old zinc	1,043	10,051	--	10,571	10,571	523
Remelt zinc	184	2,553	1,977	--	1,977	760
Engravers' plates	69	722	--	735	735	56
Rod and die scrap	198	2,823	--	2,214	2,214	807
Diecastings	1,159	8,485	--	8,339	8,339	1,305
Fragmentized diecastings	2,517	21,834	--	21,932	21,932	2,419
Remelt die-cast slab	2,449	8,339	--	9,433	9,433	1,355
Skimmings and ashes	8,686	36,448	36,255	--	36,255	8,879
Sal skimmings	27	740	636	--	636	131
Die-cast skimmings	1,853	4,502	5,015	--	5,015	1,340
Galvanizers' dross	31,254	46,418	57,224	--	57,224	20,448
Flue dust	3,878	9,526	9,280	--	9,280	4,124
Chemical residues	295	2,976	2,976	--	2,976	295
Other	--	1,168	1,112	--	1,112	56
Total	53,724	157,278	115,245	53,224	168,469	42,533
Chemical plant, foundries, and other manufacturers:						
Old zinc	10	24	--	24	24	10
Rod and die scrap	7	121	--	104	104	24
Diecastings	17	91	--	90	90	18
Skimmings and ashes	3,114	6,094	5,906	--	5,906	3,302
Sal skimmings	1,499	3,668	3,661	--	3,661	1,506
Die-cast skimmings	182	694	726	--	726	150
Galvanizers dross	25	750	773	--	773	2
Flue dust	565	7,294	6,205	--	6,205	1,654
Chemical residues	3,872	7,891	7,998	--	7,998	3,765
Other	273	9,569	9,751	--	9,751	91
Total	9,564	36,196	35,020	218	35,238	10,522
All classes of consumers:						
New clippings	112	693	770	--	770	35
Old zinc	1,053	10,075	--	10,595	10,595	533
Remelt zinc	184	2,553	1,977	--	1,977	760
Engravers' plates	69	722	--	735	735	56
Rod and die scrap	205	2,944	--	2,818	2,318	831
Diecastings	1,176	8,576	--	8,429	8,429	1,323
Fragmentized diecastings	2,517	21,834	--	21,932	21,932	2,419
Remelt die-cast slab	2,449	8,339	--	9,433	9,433	1,355
Skimmings and ashes	11,800	42,542	42,161	--	42,161	12,181
Sal skimmings	1,526	4,408	4,297	--	4,297	1,637
Die-cast skimmings	2,035	5,196	5,741	--	5,741	1,490
Galvanizers' dross	31,279	47,168	57,997	--	57,997	20,450
Flue dust	4,443	16,820	15,485	--	15,485	5,778
Chemical residues	4,167	10,867	10,974	--	10,974	4,060
Other	273	10,737	10,863	--	10,863	147
Total	63,288	193,474	150,265	53,442	203,707	53,055

[1] Figures partly revised.

Table 17.—Production of zinc products from zinc-base scrap in the United States

(Metric tons)

Products	1975	1976	1977	1978	1979
Redistilled slab zinc	52,513	62,192	45,913	34,774	53,212
Zinc dust	32,186	36,715	35,992	33,346	34,141
Remelt zinc	115	310	268	94	89
Remelt die-cast slab	4,381	4,208	3,535	3,775	3,911
Zinc-die and diecasting alloys	4,300	6,395	7,560	6,024	6,328
Galvanizing stocks	1,302	2,255	2,088	2,686	2,731
Secondary zinc in chemical products	29,906	44,435	55,312	58,649	62,494

Table 18.—Zinc recovered from scrap processed in the United States, by kind of scrap and form of recovery

(Metric tons)

	1978	1979
KIND OF SCRAP		
New scrap:		
Zinc-base	129,657	150,008
Copper-base	132,165	138,565
Magnesium-base	211	222
Total	262,033	288,795
Old scrap:		
Zinc-base	50,545	52,691
Copper-base	25,458	27,824
Aluminum-base	557	524
Magnesium-base	228	196
Total	76,788	81,235
Grand total	338,821	370,030
FORM OF RECOVERY		
As metal:		
By distillation:		
Slab zinc[1]	34,774	53,212
Zinc dust	33,346	34,141
By remelting	2,780	2,820
Total	70,900	90,173
In zinc-base alloys	9,799	10,239
In brass and bronze	198,477	206,181
In aluminum-base alloys	557	524
In magnesium-base alloys	438	418
In chemical products:		
Zinc oxide (lead free)	29,516	31,316
Zinc sulfate	10,914	13,318
Zinc chloride	18,597	12,259
Miscellaneous	4,623	5,602
Total	267,921	279,857
Grand total	338,821	370,030

[1] Includes zinc content of redistilled slab made from remelt die-cast slab.

Table 19.—Zinc dust produced in the United States

Year	Quantity (metric tons)	Value	
		Total (thousands)	Average per pound
1975	38,237	$40,294	$0.478
1976	42,055	45,282	.488
1977	43,177	45,414	.477
1978	38,487	37,427	.441
1979	33,011	32,909	.452

Table 20.—Consumption of zinc in the United States

(Metric tons)

	1975	1976	1977	1978	1979
Slab zinc	839,445	1,028,876	999,505	1,050,585	1,000,696
Ores (zinc content)[1]	75,053	91,844	86,490	89,959	79,710
Secondary (zinc content)[2]	202,986	273,524	281,709	301,266	313,908
Total	1,117,484	1,394,244	1,367,704	1,441,810	1,394,314

[1] Includes ore used directly in galvanizing.
[2] Excludes redistilled slab and remelt zinc.

Table 21.—Slab zinc consumption in the United States, by industry use

(Metric tons)

Industry and product	1975	1976	1977	1978	1979
Galvanizing:					
Sheet and strip	168,550	221,998	236,025	268,637	267,825
Wire and wire rope	22,630	24,314	21,459	22,801	23,557
Tubes and pipe	42,801	44,423	42,657	47,379	45,643
Fittings (for tube and pipe)	5,769	5,851	5,820	6,926	8,231
Tanks and containers	1,739	3,017	3,057	2,896	4,081
Structural shapes	37,408	33,204	26,623	33,264	33,875
Fasteners	4,015	3,654	3,891	4,889	4,993
Pole-line hardware	4,476	4,289	4,475	4,869	4,839
Fencing, wire cloth, and netting	18,190	19,964	20,371	24,997	21,920
Other and unspecified uses	36,328	32,172	32,060	37,356	37,839
Total	341,906	392,886	396,438	454,014	452,803
Brass products:					
Sheet, strip, plate	58,929	82,696	70,168	70,181	64,222
Rod and wire	30,314	49,489	39,525	46,284	51,130
Tube	5,852	6,702	5,542	6,779	6,690
Castings and billets	2,793	3,847	4,076	4,427	3,634
Copper-base ingots	6,008	6,968	7,544	6,581	6,800
Other copper-base products	726	1,112	1,455	7,236	8,928
Total	104,622	150,814	128,310	141,488	141,404
Zinc-base alloy:					
Diecasting alloy	299,543	380,753	359,744	345,968	308,722
Dies and rod alloy	135	932	557	544	68
Slush and sand casting alloy	3,495	5,711	6,829	7,622	5,266
Total	303,173	387,396	367,130	354,134	314,056
Rolled zinc	24,773	27,088	27,406	24,869	22,044
Zinc oxide	35,398	35,405	38,514	37,202	35,513
Other uses:					
Light-metal alloys	5,291	5,232	5,585	11,030	12,850
Other[1]	24,282	30,055	36,122	27,848	21,936
Total	29,573	35,287	41,707	38,878	34,786
Grand total	839,445	1,028,876	999,505	1,050,585	1,000,606

[1] Includes zinc used in making zinc dust, wet batteries, desilverizing lead, powder, alloys, chemicals, castings, and miscellaneous uses not elsewhere mentioned.

Table 22.—Slab zinc consumption in the United States in 1978 by grade and industry use

(Metric tons)

Industry	Special High Grade	High Grade	Intermediate	Brass Special	Prime Western	Remelt	Total
Galvanizing	27,886	35,420	9,716	95,811	284,190	991	454,014
Brass and bronze	55,170	68,319	35	2,545	15,366	53	141,488
Zinc-base alloys	352,197	1,169	--	--	160	608	354,134
Rolled zinc	12,790	--	12,079	--	--	--	24,869
Zinc oxide	18,273	--	--	--	18,929	--	37,202
Other	25,007	4,835	--	--	9,036	--	38,878
Total	491,323	109,743	21,830	98,356	327,681	1,652	1,050,585

Table 23.—Slab zinc consumption in the United States in 1979, by grade and industry use

(Metric tons)

Industry	Special High Grade	High Grade	Intermediate	Brass Special	Prime Western	Remelt	Total
Galvanizing	26,566	31,478	10,630	85,403	297,628	1,098	452,803
Brass and bronze	50,671	70,762	30	1,415	18,302	224	141,404
Zinc-base alloys	311,593	871	--	--	133	1,459	314,056
Rolled zinc	10,185	--	11,859	--	--	--	22,044
Zinc oxide	18,883	144	--	--	16,486	--	35,513
Other	25,207	5,330	--	1	4,248	--	34,786
Total	443,105	108,585	22,519	86,819	336,797	2,781	1,000,606

Table 24.—Rolled zinc produced and quantity available for consumption in the United States

	1978			1979		
		Value			Value	
	Metric tons	Total (thousands)	Average per pound	Metric tons	Total (thousands)	Average per pound
Production:[1]						
Photoengraving plate	W	W	W	W	W	W
Strip and foil	18,617	$18,467	$0.534	16,374	$19,598	$0.616
Total rolled zinc[2]	23,586	24,709	.475	21,100	26,944	.579
Exports	2,262	3,414	.685	1,824	3,385	.842
Imports	337	305	.411	244	267	.496
Available for consumption	21,803	XX	XX	19,545	XX	XX

XX Not applicable. W Withheld to avoid disclosing company proprietary data, included in "Total rolled zinc."

[1] Figures represent net production. In addition, 19,788 tons in 1978 and 18,556 tons in 1979 were rerolled from scrap originating in fabricating plants operating in connection with zinc-rolling mills.

[2] Includes other plate over 0.375 inch thick, sheet zinc less than 0.375 inch thick, and rod and wire. Bureau of Mines not at liberty to publish separately.

Table 25.—Slab zinc consumption in the United States in 1978, by industry and State

(Metric tons)

State	Galvanizers	Brass mills[1]	Die casters[2]	Other[3]	Total
Alabama	27,849	W	--	W	29,854
Arizona	W	--	--	W	W
Arkansas	W	--	--	W	W
California	29,365	2,439	19,758	1,211	52,773
Colorado	W	--	W	W	W
Connecticut	2,241	27,284	W	W	35,849
Delaware	W	W	--	W	W
Florida	3,763	--	--	--	3,763
Georgia	W	--	W	--	W
Hawaii	W	--	--	--	W
Idaho	--	--	W	W	W
Illinois	58,316	28,871	60,468	6,658	154,313
Indiana	65,531	W	9,682	W	95,469
Iowa	186	--	W	W	2,058
Kansas	W	W	W	W	W
Kentucky	W	W	--	--	16,312
Louisiana	2,868	--	W	W	4,701
Maine	W	--	--	--	W
Maryland	W	--	--	W	18,836
Massachusetts	W	W	--	W	4,893
Michigan	1,778	18,130	63,193	975	84,076
Minnesota	779	--	--	--	779
Mississippi	1,608	--	--	--	1,608
Missouri	6,354	W	W	W	10,338
Nebraska	4,314	W	--	W	4,870
New Jersey	1,757	5,055	W	W	13,772
New York	16,147	W	80,573	W	114,857
North Carolina	W	--	W	W	W
Ohio	65,491	W	48,031	W	123,061
Oklahoma	W	--	--	W	4,539
Oregon	1,139	W	W	W	1,735
Pennsylvania	60,657	8,284	W	W	133,774
Rhode Island	W	W	--	W	W
South Carolina	W	--	--	--	W
Tennessee	W	--	W	W	W
Texas	18,340	W	W	W	38,771
Utah	W	W	--	--	W
Virginia	W	W	W	W	652
Washington	W	--	--	W	2,466
West Virginia	W	--	--	W	26,169
Wisconsin	808	W	5,748	W	9,792
Undistributed	83,732	51,732	66,078	92,105	58,844
Total[4]	453,023	141,435	353,526	100,949	1,048,933

W Withheld to avoid disclosing company proprietary data; included with "Undistributed."

[1] Includes brass mills, brass ingot makers, and brass foundries.

[2] Includes producers of zinc-base alloy for diecastings, stamping dies, and rods.

[3] Includes slab zinc used in rolled zinc products and in zinc oxide.

[4] Excludes remelt zinc.

Table 26.—Slab zinc consumption in the United States in 1979, by industry and State

(Metric tons)

State	Galvanizers	Brass mills[1]	Die casters[2]	Other[3]
Alabama	26,964	W	--	W
Arizona	W	--	--	W
Arkansas	W	--	W	W
California	34,591	2,773	16,952	1,105
Colorado	W	--	W	W
Connecticut	2,782	37,538	W	W
Delaware	W	W	--	W
Florida	3,726	--	--	--
Georgia	W	--	W	--
Hawaii	W	--	--	--
Idaho	--	--	W	W
Illinois	61,587	23,724	46,735	6,896
Indiana	59,510	W	6,907	W
Iowa	239	--	W	W
Kansas	W	W	W	W
Kentucky	W	W	--	--
Louisiana	2,436	--	W	W
Maine	W	--	--	--
Maryland	W	--	--	W
Massachusetts	W	W	--	W
Michigan	1,413	15,958	56,881	564
Minnesota	700	--	--	--
Mississippi	1,481	--	--	--
Missouri	6,880	W	W	W
Nebraska	6,642	W	W	W
New Jersey	1,725	4,832	W	W
New York	15,838	W	74,591	W
North Carolina	W	--	W	W
Ohio	66,392	W	39,422	W
Oklahoma	W	--	--	W
Oregon	1,119	W	W	W
Pennsylvania	57,059	7,924	W	W
Rhode Island	W	W	--	W
South Carolina	W	--	--	--
Tennessee	W	--	W	W
Texas	16,445	W	W	W
Utah	W	W	--	--
Virginia	W	W	W	W
Washington	W	--	--	W
West Virginia	W	--	--	W
Wisconsin	843	W	5,783	W
Undistributed	83,333	48,431	65,327	83,777
Total[4]	451,705	141,180	312,598	92,342

W Withheld to avoid disclosing company proprietary data; included with "Undistributed."

[1] Includes brass mills, brass ingot makers, and brass foundries.

[2] Includes producers of zinc-base alloy for diecastings, stamping dies, and rods.

[3] Includes slab zinc used in rolled zinc products and in zinc oxide.

[4] Excludes remelt zinc.

Table 27.—Production and shipments of zinc pigments and compounds[1] in the United States

Pigment or compound	1978				1979			
	Production (metric tons)	Shipments			Production (metric tons)	Shipments		
		Quantity (metric tons)	Value[2]			Quantity (metric tons)	Value[2]	
			Total (thousands)	Average per ton			Total (thousands)	Average per ton
Zinc oxide[3]	186,797	181,452	$133,703	$668	172,729	179,769	$156,297	$782
Zinc sulfate	39,122	36,958	11,505	282	46,765	45,770	12,332	244
Zinc chloride, 50°Baumé[4]	31,937	24,767	W	W	26,601	20,003	W	W

W Withheld to avoid dislosing company proprietary data.

[1] Excludes leaded zinc oxide and lithopone.

[2] Value at plant, exclusive of container.

[3] Zinc oxide containing 5% or more lead is classed as leaded zinc oxide.

[4] Includes zinc content of zinc ammonium chloride and chromated zinc chloride.

Table 28.—Zinc content of zinc pigments[1] and compounds produced by domestic manufacturers, by source

(Metric tons)

Pigment or compound	1978				1979			
	Zinc in pigments and compounds produced from—			Total zinc in pigments and compounds	Zinc in pigments and compounds produced from—			Total zinc in pigments and compounds
	Ore	Slab zinc	Secondary material		Ore	Slab zinc	Secondary material	
Zinc oxide	84,615	35,370	29,516	149,501	74,324	32,567	31,316	138,207
Zinc sulfate	1,560	--	10,915	12,475	887	--	13,318	14,205
Zinc chloride[2]	--	--	10,628	10,628	--	--	8,931	8,931

[1] Excludes leaded zinc oxide, zinc sulfide, and lithopone.
[2] Includes zinc content of zinc ammonium chloride and chromated zinc chloride.

Table 29.—Distribution of zinc oxide shipments, by industry

(Metric tons)

Industry	1975	1976	1977	1978	1979
Rubber	87,279	94,954	101,729	97,969	93,078
Paints	9,994	14,242	12,519	13,237	12,508
Ceramics	5,715	7,650	7,354	9,245	9,296
Chemicals	15,916	30,106	26,327	27,057	27,710
Agriculture	1,676	3,158	5,499	4,847	4,397
Photocopying	22,359	21,907	21,352	19,096	16,148
Other	10,815	7,676	15,322	9,961	16,700
Total	153,754	179,698	190,102	181,452	179,769

Table 30.—Distribution of zinc sulfate shipments, by industry

(Metric tons)

Year	Agriculture		Other[1]		Total	
	Gross weight	Dry basis	Gross weight	Dry basis	Gross weight	Dry basis
1975	7,684	3,247	13,628	5,309	21,312	8,556
1976	11,609	4,832	19,547	9,328	31,156	14,160
1977	14,085	5,553	19,962	8,840	34,047	14,393
1978	19,261	7,268	17,697	6,741	36,958	14,009
1979	31,318	11,122	14,452	5,659	45,770	16,781

[1] Includes rayon; Bureau of Mines not at liberty to publish separately.

Table 31.— Producer stocks of slab zinc in the United States, December 31

(Metric tons)

	1975	1976	1977	1978	1979
Primary producers	66,616	83,963	76,637	34,570	56,971
Secondary producers	1,129	3,989	[r]7,123	3,358	2,095
Total	67,745	87,952	[r]83,760	37,928	59,066

[r] Revised.

Table 32.—Consumer stocks of slab zinc at plants, December 31, by grade

(Metric tons)

Year	Special High Grade	High Grade	Inter-mediate	Brass Special	Prime Western	Remelt	Total
1977[r]	30,165	7,606	3,159	9,102	36,404	41	86,477
1978	36,599	9,754	2,871	6,063	43,855	183	99,325
1979	34,913	9,714	2,806	3,886	41,946	69	93,334

[r] Revised.

Table 33.—Average monthly U.S., LME,[1] and European Producers' prices for Prime Western zinc and equivalent

(Metallic zinc, cents per pound)

Month	1978			1979		
	United States	LME cash	European producer	United States	LME cash	European producer
January	30.50	23.47	27.22	34.57	32.64	33.32
February	30.06	21.62	25.33	35.62	35.92	35.58
March	29.00	23.01	24.95	37.24	36.00	36.29
April	29.00	25.12	24.95	38.99	35.74	36.29
May	29.00	25.43	24.95	39.39	35.28	36.57
June	29.01	26.17	24.95	39.39	34.13	38.38
July	29.80	26.45	24.95	39.40	32.69	37.35
August	31.16	28.01	26.77	36.90	30.12	35.38
September	32.37	28.73	28.92	35.80	32.79	35.38
October	32.83	32.31	31.30	36.21	32.00	35.38
November	34.43	31.15	32.66	38.82	31.76	35.38
December	34.50	31.14	32.66	37.23	33.98	35.38
Average for year	30.97	26.88	27.47	37.30	33.59	35.89

[1] London Metal Exchange.

Source: Metals Week.

Table 34.—U.S. exports of zinc and zinc alloys, by country

Destination	1977		1978		1979	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Unwrought zinc and zinc alloys:						
Argentina	18	$34	8	$34	42	$77
Australia	--	--	18	81	5	25
Bahrain	40	82	--	--	--	--
Belgium-Luxembourg	--	--	5	11	3	16
Canada	415	458	333	409	98	277
Chile	13	16	39	27	29	47
Colombia	1	1	5	10	2	4
Dominican Republic	4	13	1	2	90	76
Ecuador	--	--	64	61	1	5
Egypt	104	90	--	--	27	56
France	(1)	1	(1)	4	--	--
Germany, Federal Republic of	4	12	9	6	14	23
Guatemala	125	121	(1)	2	1	3
Honduras	--	--	1	8	--	--
India	--	--	350	255	--	--
Indonesia	--	--	--	--	--	--
Iran	--	--	59	59	--	--
Israel	8	17	1	2	20	36
Italy	4	3	1	9	2	2
Japan	34	20	35	84	9	22
Korea, Republic of	--	--	(1)	1	(1)	5
Liberia	--	--	2	4	2	5
Mexico	98	50	215	127	98	242
Netherlands	2	6	2	1	19	25
Netherlands Antilles	--	--	1	4	--	2
New Zealand	--	--	1	5	(1)	2
Nicaragua	1	2	2	2	--	--
Nigeria	--	--	5	12	2	3
Philippines	11	11	7	14	7	9
Saudi Arabia	1	2	26	31	60	100
Singapore	--	--	--	--	--	--

See footnotes at end of table.

Table 34.—U.S. exports of zinc and zinc alloys, by country —Continued

Destination	1977		1978		1979	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Unwrought zinc and zinc alloys: —Continued						
South Africa, Republic of	--	--	18	$95	31	[illegible]
Switzerland	--	--	9	21	3	7
Taiwan	48	$52	8	10	11	41
United Arab Emirates	(1)	1	--	--	3	4
United Kingdom	4	8	5	18	9	115
Venezuela	29	40	24	104	31	42
Other	165	228	23	50	26	66
Total	1,114	1,279	1,277	1,563	645	[illegible]
Wrought zinc and zinc alloys:						
Afghanistan	19	28	10	14	--	--
Algeria	--	--	13	26	--	--
Argentina	16	27	65	106	86	147
Australia	85	170	12	33	9	12
Austria	--	--	10	24	19	[illegible]
Belgium-Luxembourg	2,057	1,191	7	15	110	64
Bermuda	1	1	12	11	--	--
Canada	3,338	2,790	1,453	1,641	897	[illegible]
Chile	34	56	60	113	12	18
Colombia	47	70	48	60	33	55
Denmark	24	53	2	2	3	6
Dominican Republic	1	1	4	5	70	106
Ecuador	53	105	61	157	552	[illegible]
Egypt	42	61	15	22	22	[illegible]
El Salvador	33	26	8	14	--	--
France	5	13	4	5	9	10
Germany, Federal Republic of	--	--	12	31	--	--
Greece	16	23	14	22	8	12
Guatemala	13	17	15	30	5	[illegible]
Guyana	6	15	12	34	4	9
Hong Kong	34	50	135	194	33	40
India	9	12	24	37	28	46
Israel	57	77	69	108	54	[illegible]
Italy	34	56	82	201	90	173
Japan	17	72	3	8	18	[illegible]
Kuwait	--	--	5	33	1	2
Lebanon	24	38	30	48	15	25
Malaysia	--	--	15	19	50	[illegible]
Mexico	102	134	104	195	164	276
Netherlands	4	23	7	4	--	--
New Zealand	63	84	31	41	18	[illegible]
Pakistan	21	32	15	23	14	[illegible]
Panama	22	47	2	3	3	7
Peru	32	54	16	27	62	[illegible]
Philippines	43	89	69	105	61	[illegible]
Portugal	5	9	35	65	38	67
Saudi Arabia	7	12	48	62	33	[illegible]
Singapore	7	17	9	18	38	31
South Africa, Republic of	96	154	76	125	100	179
Spain	2	4	25	42	69	115
Sri Lanka	21	33	15	22	38	[illegible]
Sweden	25	33	1	3	4	9
Switzerland	26	41	--	--	--	--
Syria	37	61	16	26	10	18
Taiwan	53	76	69	111	241	[illegible]
Thailand	--	--	25	36	12	17
Turkey	32	30	21	30	7	12
United Arab Emirates	5	8	--	--	--	--
United Kingdom	290	311	156	277	79	[illegible]
Uruguay	6	7	6	17	27	40
Venezuela	157	235	100	136	49	[illegible]
Other	80	227	76	115	89	173
Total	7,110	6,693	3,122	4,506	3,285	[illegible]

[1] Less than 1/2 unit.

Table 35.—U.S. exports of zinc, by class

Year	Zinc ore and concentrates		Blocks, pigs, anodes, etc.				Wrought zinc and zinc alloys				Waste and scrap (zinc content)		Dust (blue powder)	
			Unwrought		Unwrought alloys		Sheets, plates, and strip		Angels, bars, pipes, rods, etc.					
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1977	NA	NA	215	$210	899	$1,069	2,432	$3,144	4,677	$3,549	7,445	$2,972	928	$726
1978	10,973	$4,356	723	865	r554	r698	2,262	3,414	860	1,091	14,966	6,738	1,308	2,018
1979	20,095	7,317	279	553	366	832	1,824	3,385	1,461	1,839	28,140	14,142	966	1,450

rRevised.
NA Not available.

Table 36.—U.S. exports of zinc ore and concentrates, by country

(Zinc content)

Destination	1978		1979	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Belgium-Luxembourg	7,579	$2,966	10,985	$3,596
Brazil	13	5	--	--
Canada	254	111	1,574	1,275
Chile	20	17	755	367
Germany, Federal Republic of	6	1	--	--
Nigeria	--	--	3	6
Philippines	1	1	--	--
Saudi Arabia	1	1	33	22
Sweden	2	5	--	--
Taiwan	77	86	75	85
Trinidad and Tobago	4	3	--	--
United Kingdom	3,016	1,230	6,716	2,011
Venezuela	--	--	4	8

Table 37.—U.S. general imports of zinc, by country

Country	1977		1978		1979	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
ORES AND CONCENTRATES (zinc content)						
Argentina	--	--	--	--	3	$3
Australia	3,940	$968	1,851	$617	708	94
Bolivia	4,528	673	397	72	11,935	5,167
Canada	53,141	21,064	143,318	50,408	143,957	57,942
Chile	10,690	3,750	5,933	3,347	1,240	668
Colombia	16	2	10	1	16	2
Costa Rica	772	553	--	--	--	--
Germany, Federal Republic of	737	302	6,535	2,564	7,802	4,101
Greenland	--	--	--	--	--	--
Honduras	15,757	8,275	13,141	4,888	13,383	5,113
Japan	--	--	101	39	--	--
Mexico	3,891	615	2,613	813	16,207	5,007
Nicaragua	2,768	1,907	4,046	1,681	4	3
Peru	938	141	10,058	2,885	29,697	14,419
Thailand	14,232	1,308	--	--	--	--
Total	111,410	39,553	188,003	67,815	224,952	92,519
BLOCKS, PIGS, OR SLABS						
Algeria	1,159	557	2,547	1,518	5,317	4,250
Australia	26,546	19,612	34,785	21,992	33,721	25,684
Belgium-Luxembourg	38,983	24,686	19,215	10,596	11,228	8,158
Canada	217,321	160,224	261,842	172,412	259,543	197,270
China:						
Mainland	1,006	615	801	384	208	90
Taiwan	--	--	--	--	104	16
Finland	29,637	21,245	32,964	21,535	26,410	21,361
France	15,810	11,021	22,824	13,875	13,445	10,608
Germany, Federal Republic of	37,605	25,886	36,955	22,058	19,110	14,818
Greece	--	--	244	144	--	--
Italy	19,597	13,844	11,149	6,303	5,492	3,899
Japan	13,021	9,769	8,605	6,290	10,118	7,971
Korea, Republic of	--	--	4,000	2,402	2,300	1,721
Mexico	27,196	18,826	51,471	30,433	39,332	28,873
Morocco	--	--	2,080	1,002	--	--
Netherlands	5,828	3,737	10,097	5,673	3,180	2,314
Norway	--	--	--	--	--	--
Peru	17,132	11,740	10,245	6,002	7,394	5,408
Poland	3,575	1,991	5,670	2,828	100	75
South Africa, Republic of	5,339	3,811	8,112	4,872	--	--
Spain	25,709	16,821	60,225	33,931	66,738	43,703
Switzerland	--	--	--	--	--	--
Tanzania	--	--	1,001	595	1,200	848
Hong Kong	--	--	--	--	105	79
United Kingdom	1,490	981	997	565	2,383	1,315
Yugoslavia	3,242	2,101	3,777	2,082	--	--
Zaire	32,393	23,910	25,680	14,682	14,880	11,812
Zambia	525	359	2,604	1,261	4,904	2,277
Total	523,206	371,736	617,840	383,434	527,212	392,551

Table 38.—U.S. imports for consumption of zinc, by country

Country	1977 Quantity (metric tons)	1977 Value (thousands)	1978 Quantity (metric tons)	1978 Value (thousands)	1979 Quantity (metric tons)	1979 Value (thousands)
ORES AND CONCENTRATES (zinc content)						
Argentina	--	--	--	--	3	$3
Australia	3,318	$896	1,346	$489	50	7
Bolivia	4,528	673	397	72	11,935	5,157
Canada	54,804	21,621	66,551	21,744	9,912	3,277
Chile	10,690	3,751	5,933	3,347	1,240	683
Colombia	16	2	10	1	16	2
Germany, Federal Republic of	737	302	6,535	2,564	7,802	4,101
Greenland	--	--	--	--	--	--
Honduras	15,757	8,275	13,141	4,888	13,383	5,112
Japan	--	--	101	39	--	--
Mexico	3,400	526	959	535	13,457	4,340
Nicaragua	857	407	2,727	1,066	4	3
Peru	938	141	8,615	2,425	29,697	14,419
Thailand	14,232	1,303	--	--	--	--
Total	109,277	37,897	106,315	37,170	87,499	37,104
BLOCKS, PIGS, OR SLABS						
Algeria	881	407	2,547	1,518	4,276	3,415
Angola	--	--	--	--	989	793
Australia	26,546	19,612	34,785	21,992	33,721	25,634
Belgium-Luxembourg	37,482	23,986	19,165	10,565	12,327	9,061
Canada	217,321	160,224	261,841	172,411	259,543	197,270
China:						
Mainland	829	536	801	384	236	93
Taiwan	--	--	--	--	104	16
Finland	29,537	21,115	32,964	21,535	25,160	20,298
France	16,981	11,999	22,477	8,238	13,792	10,873
Germany, Federal Republic of	37,695	25,886	36,955	22,058	19,110	14,813
Ghana	--	--	--	--	1,003	589
Greece	--	--	244	144	--	--
Italy	16,597	11,909	14,148	13,610	5,492	3,880
Japan	--	--	4,990	3,547	10,118	7,971
Korea, Republic of	--	--	4,000	2,402	2,300	1,721
Mexico	29,022	20,418	48,712	28,865	36,833	27,385
Morocco	--	--	2,080	1,002	--	--
Netherlands	4,451	2,808	11,098	6,357	3,180	2,314
Norway	--	--	--	--	--	--
Peru	18,931	13,020	10,245	6,002	7,394	5,488
Poland	3,575	1,991	5,670	2,828	100	75
Romania	--	--	--	--	--	--
South Africa, Republic of	5,839	3,811	8,112	4,872	--	--
Spain	21,309	14,416	64,626	36,336	66,738	43,703
Switzerland	--	--	--	--	1	1
Tanzania	--	--	1,001	595	1,200	848
United Kingdom	1,490	961	997	565	2,383	1,315
Yugoslavia	2,918	1,923	3,777	2,082	--	--
Zaire	32,192	23,733	28,630	16,913	14,829	11,767
Zambia	525	359	2,605	1,261	3,301	1,276
Total	503,621	359,134	622,470	386,082	524,130	390,599

Table 39.—U.S. imports for consumption of zinc, by class

	Ore (zinc content)		Blocks, pigs, slabs[1]		Sheets, plates, strips other forms		Waste and scrap	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1977	109,277	$37,897	503,621	$359,134	186	$211	9,188	$2,175
1978	106,315	37,170	622,470	386,082	337	305	3,310	1,250
1979	87,499	37,104	524,130	390,599	244	267	3,259	1,530

	Dross and skimmings (zinc content)		Zinc fume (zinc content)		Dust, powder, flakes		Total value[2] (thousands)
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	
1977	11,789	$5,294	233	$516	6,702	$6,277	$411,414
1978	7,486	2,104	60	10	8,978	7,455	434,376
1979	4,454	1,735	28	2	3,586	3,440	434,677

[1] Unwrought alloys of zinc were imported as follows: 1977, 321 metric tons ($211,624); 1978, 23 metric tons ($13,319); and 1979, 78 metric tons ($72,725).

[2] In addition, manufactures of zinc were imported as follows: 1977, $261,554; 1978, $461,880; 1979, $213,669.

Table 40.—U.S. imports for consumption of zinc pigments and compounds

Kind	1978		1979	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Zinc oxide	24,392	$16,956	26,912	$21,415
Zinc sulfide	846	723	741	[illegible]
Lithopone	129	67	168	91
Zinc chloride	1,440	891	1,201	788
Zinc sulfate	5,716	1,992	6,849	26,370
Zinc cyanide	39	625	41	[illegible]
Zinc hydrosulfite	300	209	336	[illegible]
Zinc compounds, n.s.p.f.	707	785	823	[illegible]
Total	33,569	22,248	37,071	50,617

Table 41.—Zinc: World mine production (content of ore), by country

(Thousand metric tons)

Continent and country	1976	1977	1978[p]	1979[e]
North America:				
Canada[1]	[r]982.1	1,070.5	1,066.9	[2]1,148.5
Guatemala	[r].5	1.0	1.0	[1]1.0
Honduras	24.8	26.5	24.3	22.0
Mexico[1]	259.2	265.5	244.9	240
Nicaragua	14.3	10.1	3.6	--
United States[1]	439.5	407.9	302.7	[2]267.3
South America:				
Argentina	[r]40.6	39.2	36.9	38.0
Bolivia	48.5	61.4	53.9	[2]51.6
Brazil	[r]69.6	81.2	81.6	80.0
Chile[1]	5.0	3.9	1.8	1.9
Colombia	.1	--	--	--
Ecuador	.1	2.0	1.2	2.0
Peru[1]	421.3	405.4	457.5	490.0
Europe:				
Austria	17.6	19.7	22.5	20.0
Bulgaria[e]	85.5	87.0	88.0	89.0
Czechoslovakia	9.3	9.4	8.8	9.1
Finland	61.1	62.9	52.9	[2]54.6
France	34.7	41.8	39.9	[2]35.9
Germany, Federal Republic of[3]	111.2	111.4	97.4	[2]96.9
Greece	26.5	18.0	25.6	[2]25.7
Greenland	81.0	76.6	82.4	[2]87.3
Hungary	2.2	2.8	2.6	2.5
Ireland	62.8	116.3	176.0	[2]212.3
Italy	[r]86.4	79.8	73.8	[2]65.5
Norway	[r]29.1	31.3	28.9	29.0
Poland	[r]180.0	188.0	194.0	190.0
Romania	[r] [e]67.0	[r] [e]62.0	60.0	60.0
Spain	[r]83.7	96.3	143.5	[2]136.3
Sweden	128.3	140.2	162.8	[2]164.4
U.S.S.R.[1] [e]	720.0	735.0	770.0	770.0
United Kingdom	4.8	7.7	2.7	--
Yugoslavia	106.6	112.4	97.4	[2]112.4
Africa:				
Algeria	[r]6.9	2.7	4.8	6.0
Congo (Brazzaville)	[r]5.3	5.3	4.8	5.0
Morocco	[r]17.7	7.8	4.3	12.0
Nigeria	.4	--	--	--
South Africa, Republic of	82.6	76.8	71.8	55.0
South West Africa[e]	45.5	42.2	40.3	56.8
Tunisia	7.3	7.1	7.4	7.4
Zaire	67.8	73.0	73.7	68.0
Zambia[1]	48.8	45.0	45.0	45.0
Asia:				
Burma	2.2	1.8	2.6	3.0
China, Mainland[1] [e]	100.0	100.0	120.0	120.0
Cyprus	.9	.2	--	--
India	27.4	32.5	39.8	39.0
Iran	72.0	61.5	[e]45.0	40.0
Japan[1]	280.0	275.7	275.1	[2]243.3
Korea, North[1] [e]	150.0	150.0	140.0	140.0
Korea, Republic of	59.1	68.4	66.4	[2]62.4
Philippines	[r]11.6	12.4	9.3	[2]9.7
Thailand[3]	([4])	.3	--	--
Turkey[e]	42.8	67.1	40.7	46.0
Vietnam[e]	10.0	10.0	8.0	6.0
Oceania:				
Australia	[r]468.6	491.6	473.3	530.0
Total	[r]5,690.3	5,906.1	5,877.8	5,977.8

[e]Estimate. [p]Preliminary. [r]Revised.

[1] Recoverable content of concentrates.

[2] Reported figure.

[3] Content of zinc concentrates; additional quantities of zinc may be contained in lead concentrates produced, but information is inadequate to make reliable estimates of such production.

[4] Less than 1/2 unit.

Table 42.—Zinc: World smelter production by country[1]

(Thousand metric tons)

Country	1976	1977	1978[p]	1979[e]
North America:				
Canada, primary	472.3	494.9	495.4	[2]580.4
Mexico, primary	[r]175.2	174.4	173.1	160.0
United States:				
Primary	452.5	408.4	406.7	[2]472.5
Secondary	62.2	45.9	34.8	[2]53.2
Total	514.7	454.3	441.5	[2]525.7
South America:				
Argentina, primary	35.2	29.0	23.9	37.0
Brazil:				
Primary	43.2	47.5	57.0	65.0
Secondary	7.0	9.5	12.0	14.0
Total	50.2	57.0	69.0	79.0
Peru, primary	[r]54.7	66.9	68.4	69.0
Europe:				
Austria, primary and secondary	16.5	16.7	21.7	23.0
Belgium:				
Primary	[r]234.7	247.6	233.9	255.4
Secondary	[r]6.5	10.6	6.6	5.0
Total	241.2	258.2	240.5	[2]260.4
Bulgaria, primary and secondary	92.5	90.0	91.0	92.0
Finland, primary	110.6	138.0	132.9	[2]147.1
France:				
Primary[e]	218.3	223.3	216.2	229.0
Secondary[e]	15.0	15.0	15.0	20.0
Total	233.3	238.3	231.2	[2]249.0
German Democratic Republic, primary and secondary	15.0	15.5	16.0	16.0
Germany, Federal Republic of:				
Primary	283.4	335.1	288.7	[2]333.6
Secondary	21.4	19.7	18.1	[2]21.9
Total	304.8	354.8	306.8	[2]355.5
Greece, secondary	([3])	([3])	--	--
Hungary, secondary	.7	.6	[e].6	.6
Italy, primary and secondary	191.2	169.4	177.6	[2]202.8
Netherlands, primary and secondary	140.8	109.4	135.3	[2]154.0
Norway, primary	64.4	69.8	71.6	[2]77.5
Poland, primary and secondary	237.0	228.0	222.0	217.0
Romania, primary and secondary	[r]53.4	51.9	49.8	48.5
Spain, primary	[r]161.1	156.6	163.3	[2]179.7
U.S.S.R.:				
Primary	720.0	735.0	770.0	770.0
Secondary	80.0	80.0	80.0	80.0
Total	800.0	815.0	850.0	850.0
United Kingdom, primary and secondary	41.6	81.5	73.6	[2]76.7
Yugoslavia:				
Primary	86.5	89.2	[e]82.2	87.9
Secondary	9.0	9.6	[e]10.0	11.0
Total	95.5	98.8	92.2	[2]98.9
Africa:				
Algeria, primary	[r]20.0	20.0	25.7	17.0
South Africa, Republic of, primary[4]	[r]66.2	76.0	79.1	80.0
Zaire, primary	61.7	51.0	43.5	[2]43.7
Zambia, primary	[r]36.3	40.1	41.6	40.0
Asia:				
China, Mainland, primary and secondary	[r]100.0	[r]100.0	120.0	120.0
India, primary	26.8	36.0	59.4	[2]65.9
Japan:				
Primary	742.0	778.4	767.9	[2]789.4
Secondary	34.0	26.6	24.8	25.0
Total	776.0	805.0	792.7	814.4
Korea, North, primary[e]	135.0	135.0	130.0	130.0
Korea, Republic of, primary	27.5	32.8	59.0	83.0
Thailand, primary	([3])	([3])	([3])	--

See footnotes at end of table.

Table 42.—Zinc: World smelter production by country[1] —Continued

(Thousand metric tons)

Country	1976	1977	1978[p]	1979[e]
Asia: —Continued				
Turkey, primary	2.3	20.9	20.0	24.0
Vietnam, primary[e]	[r]9.0	9.0	7.2	5.4
Oceania: Australia:				
Primary	242.6	249.7	290.1	[2]305.4
Secondary[e]	[r]6.6	[r]6.7	4.7	4.7
Total	249.2	256.4	294.8	310.1
Grand total	5,611.9	5,751.2	5,820.4	6,233.3
Of which:				
Primary	4,481.5	4,664.6	4,706.8	5,047.9
Secondary	242.4	224.2	206.6	235.4
Undifferentiated	888.0	862.4	907.0	950.0

[e] Estimate. [p] Preliminary. [r] Revised.

[1] Table combines data provided in table 39 and 40 of the 1977 edition of this chapter. Wherever possible, detailed information on raw material source of output (primary — directly from ores, and secondary — from scrap) has been provided. In cases where raw material source is unreported and insufficient data are available to estimate the distribution of the total, that total has been left undistributed (primary and secondary). To the extent possible, this table reflects metal production at the first measurable stage of metal output.

[2] Reported figure.

[3] Less than 50 metric tons.

[4] May include small quantities of secondary.

Table 45.—Zinc: World smelter production by country—Continued

[illegible]

Zirconium and Hafnium

By Langtry E. Lynd[1]

Zircon production by domestic mining companies decreased 18% in 1978 and 5% in 1979, mainly because of mine shutdowns by Titanium Enterprises in 1978, and by Humphreys Mining Co. in 1979. Zircon exports decreased and imports increased in 1978-1979, with domestic consumption up slightly over the 2-year period. Production and shipments of zirconium mill products fell 10% in 1978 and 15% in 1979 because of slow demand for nuclear powerplant construction. Demand for hafnium strengthened, partly because of the increased use of hafnium-columbium carbide in cutting-tool alloys.

Zircon continued to be in oversupply, despite a reduction of inventories in Australia which was partly offset by increasing production of both standard and premium grade zircon from the new Richards Bay heavy minerals operation in the Republic of South Africa.

Zircon use was largely in foundry sands, refractories, abrasives, ceramics, and as a source of zirconium metal. The metal was used mostly in nuclear reactors, corrosion-resistant equipment for industrial plants, and refractory alloys. Hafnium was used in nuclear reactors, flashbulbs, refractory alloys, and cutting-tool alloys.

Legislation and Government Programs.— There were no stockpile goals for zirconium and hafnium materials. The U.S. Department of Energy (DOE) had an inventory as of December 31, 1979, of approximately 319 tons of zirconium sponge, 829 tons of zirconium ingots and shapes, 4 tons of zirconium scrap, 31 tons of hafnium crystal bar, 8 tons of hafnium ingots and shapes, 5 tons of hafnium oxide, and 1 ton of hafnium scrap.

The Department of Environmental Quality (DEQ) of the State of Oregon stated that Teledyne Wah Chang Albany (TWCA) has made great progress in cleaning up its wastewater discharges, having reduced the amount of ammonia going into the Willamette River from 20,000 pounds per day several years ago to 400 pounds per day in late 1979.[2] A new TWCA air pollution permit recommended by DEQ earlier in 1979 may allow production of zirconium oxide above the previous 50,000-pound-per-day limit, subject to additional State approval.[3] The Oregon State legislature passed a bill in 1979 which holds in abeyance until 1981

Table 1.—Salient zirconium statistics in the United States

(Short tons)

Product	1975	1976	1977	1978	1979
Zircon:					
Production	W	W	W	W	W
Exports	18,766	9,428	14,364	7,671	8,856
Imports	40,205	64,643	65,204	91,009	110,842
Consumption[e] [1]	122,000	155,000	162,000	164,000	168,000
Stock: yearend, dealers' and consumers'[2]	37,033	38,625	[r]26,052	[e]38,307	[e]37,531
Zirconium oxide:					
Production[3]	11,760	8,000	7,414	[e]8,605	[e]11,130
Producers' stocks, yearend[3]	1,745	667	[r]718	[e]931	[e]809

[e]Estimate. [r]Revised. W Withheld to avoid disclosing company proprietary data.

[1]Includes baddeleyite: 1975-[e]1,000 tons; 1976-[e]1,000 tons; 1977-[e]1,500 tons; 1978-[e]1,600 tons; 1979-[e]1,600 tons.

[2]Excludes foundries.

[3]Excludes oxide produced by zirconium metal producers.

regulations regarding the storage of low-level-radiation sludge at the TWCA plant and provides for a study by an independent research organization to determine if there is any danger from this material at its present location. The results of the study are to be reported to the 1981 session of the legislature. In the meantime, the company has modified its chlorination process to produce a more concentrated radioactive residue that could be shipped to the Hanford, Wash., disposal site.

DOMESTIC PRODUCTION

E. I. du Pont de Nemours & Co., Humphreys Mining Co., and Titanium Enterprises, Inc., were the only producers of zircon mineral concentrate in the United States in 1978-79. Zircon was recovered as a coproduct of titanium mineral concentrates from mineral sands at the dredging and milling facilities owned and operated by Du Pont at Starke and Highland, Fla.; operated by Humphreys Mining Co. for Du Pont, at Boulougne, Fla., and Folkston, Ga.; and owned and operated by Titanium Enterprises at Green Cove Springs, Fla. Production data were withheld from publication to avoid disclosing company proprietary data. The combined zircon capacity ot these three plants was estimated to be 135,000 tons per year.

The Humphreys Mining Co. operation at Boulougne, Fla., was shut down in November 1979 because of depleted reserves. Dredging and wet milling at the Titanium Enterprises facility were suspended in June 1978; the dry mill, however, continued in operation to produce zircon and monazite from stockpile tailings. In April 1980, Associated Minerals Consolidated Ltd. (AMC) announced it had exercised its option to purchase the Titanium Enterprises property at a price of $11.7 million. AMC is a subsidiary of Consolidated Gold Fields Australia Ltd. (CGFA), and expects to produce at Green Cove Springs, over the next 16 years, 25,000 tons per year of zircon, 25,000 tons per year of rutile, and 50,000 tons per year of ilmenite, as well as smaller quantities of leucoxene, staurolite, and monazite.[4]

Statistical data on production of zirconium sponge, ingot, and scrap, and on hafnium sponge and oxide are also withheld to avoid disclosing company proprietary data. Zirconium sponge production in 1978 and 1979, estimated from published information, was about 4.8 million pounds and 4.0 million pounds, respectively. U.S. annual production capacity in those years was about 8 million pounds.

Approximately 3,165 tons of alloys containing from 3% to 70% zirconium was produced in 1978, and 3,132 tons in 1979.

Four firms produced 39,993 tons of milled (ground) zircon in 1978, and 41,567 tons in 1979 from domestic and imported concentrates, compared with the reported 1977 production of 41,820 tons. Six companies, excluding those that produce metal, produced 8,605 tons of zirconium oxide in 1978, and 11,130 tons in 1979, compared with 7,400 tons in 1977.

Hafnium crystal bar production was estimated at 40 tons and 50 tons in 1978 and 1979, respectively, substantially above the estimated 35 tons produced in 1977.

TWCA was the only domestic commercial producer of zirconium and hafnium sponge in 1978 and 1979. Because of reduced demand for zirconium resulting from the slowdown in nuclear powerplant construction, TWCA was operating at about 50% of capacity in late 1979, and had laid off about 13% of its work force during the last 2 years. However, in June 1978 Westinghouse Electric Corp. announced that its recently formed subsidiary, Western Zirconium Co., would build a $50 million zirconium metal plant near Ogden, Utah.[5] Construction was completed in 1979, with commercial production scheduled to begin early in 1980. The plant reportedly has an annual production capacity of 3 to 4 million pounds of zirconium sponge metal[6], bringing total U.S. capacity to 11 to 12 million pounds per year.

In December 1978, NL Industries, Inc. announced the sale of its Taylor Refractories Division, a producer of zirconium-bearing refractories, to Didier Werke of Wiesbaden, Federal Republic of Germany. NL also announced, in October 1979, the sale of its Niagara Falls, N.Y., plant, which produces zirconium and titanate products for the foundry, refractory, and ceramic industries, to the Lead Industries Group, Ltd., of the United Kingdom. These facilities continued in operation as Didier-Taylor Refractories Corp. and TAM Ceramics, Inc.

The Norton Co. approved plans to build a $19.1 million addition to its zirconia-alumina material manufacturing plant in Huntsville, Ala., to expand production of abrasive grain for both coated abrasives and grinding wheels. Production at the new facilities was scheduled to begin in late 1980.

Table 2.—Producers of zirconium and hafnium materials in 1978 and 1979

Company	Location	Materials
ZIRCONIUM MATERIALS		
Associated Minerals Consolidated Ltd	Bow, N.H.	Oxide.
Babcock & Wilcox Co., Nuclear Materials Div.[1]	Parks Township, Pa	Powder.
The Carborundum Co	Falconer, N.Y	Refractories, oxide.
C-E Cast Industrial Products	Carson, Calif.	Milled zircon.
C-E Refractories, Div. of Combustion Engineering, Inc	St. Louis, Mo	Refractories.
Do	King of Prussia, Pa	Refractories, zircon.
Do	Vandalia, Mo	Do.
Continental Mineral Processing Corp	Sharonville, Ohio	Milled zircon.
Corhart Refractories Co	Buckhannon, W. Va	Refractories.
Do	Corning, N.Y	Do.
Do	Louisville, Ky	Do.
Didier-Taylor Refractories Corp	Cincinnati, Ohio	Refractories.
Do	South Shore, Ky	Do.
E. I. du Pont de Nemours & Co	Wilmington, Del	Zircon, foundry mixes.
Ferro Corp	Cleveland, Ohio	Ceramics, ceramic colors.
Foote Mineral Co	Cambridge, Ohio	Alloys.
A. P. Green Refractories Co., Remmey Div	Philadelphia, Pa	Refractories.
Harbison-Walker Refractories Co	Mount Union, Pa	Do.
Hercules, Inc., Drakenfeld Div.[2]	Washington, Pa	Ceramic colors, milled zircon.
Humphreys Mining Co. (now owned by Buttes Gas & Oil Co.)	Folkston, Ga	Zircon.
Lincoln Electric Co., Inc	Cleveland, Ohio	Welding rods.
M & T Chemicals, Inc	Andrews, S.C	Milled zircon.
Magnesium Elektron, Inc	Flemington, N.J	Alloys, chemicals, oxide.
NL Industries, Inc., Industrial Chemicals Div.[3]	Hightstown, N.J	Milled zircon, oxide, alloys, chloride.
Norton Co	Huntsville, Ala	Oxide.
Ronson Metals Corp	Newark, N.J	Baddeleyite (oxide).
Sherwood Refractories Co	Cleveland, Ohio	Zircon cores.
Shieldalloy Corp	Newfield, N.J	Welding rods, alloys.
Teledyne Wah Chang Albany	Albany, Oreg	Oxide, chloride, sponge, ingot, powder, crystal bar.
Titanium Enterprises, Inc	Green Cove Springs, Fla	Zircon.
Transelco, Inc	Dresden, N.Y	Chemicals, ceramics, oxide.
Union Carbide Corp	Niagara Falls, N.Y	Alloys.
Ventron Corp.[4]	Beverly, Mass	Alloys, powder.
Western Zirconium Co.[5]	Ogden, Utah	Oxide, sponge, ingot, mill products.
Zedmark, Inc	Butler, Pa	Refractories.
ZIRCOA Products	Cleveland, Ohio	Oxide, refractories, ceramics.
HAFNIUM MATERIALS		
Teledyne Wah Chang Albany	Albany, Oreg	Oxide, sponge, ingot, crystal bar.
Western Zirconium Co.[5]	Ogden, Utah	Oxide, sponge, crystal bar, ingot.

[1] 1978 only.
[2] 1979—Ciba-Geigy Corp., Drakenfeld Colors.
[3] 1979—TAM Ceramics, Niagara Falls, N.Y.
[4] 1979—Thiokol Corp., Ventron Division.
[5] Began operation late in 1979. Subsidiary of Westinghouse Electric Corp.

CONSUMPTION AND USES

Foundries used about 44% of domestic zircon consumption in 1978-1979. The remainder was consumed by refractory, abrasive, ceramic, metal, and other industries. Domestic zircon was marketed in proprietary mixtures for use as foundry sand, zircon-refractory heavy mineral sand blends (with kyanite, sillimanite, and staurolite), weighting agents, zircon-TiO_2 blends for welding rod coatings, and sandblasting applications. The zircon-bearing foundry sand was reportedly designed to provide consistent high-quality performance at low cost for critical casting applications.

In 1978 and 1979 baddeleyite concentrate from the Republic of South Africa was used mainly in the manufacture of alumina-zirconia abrasives and also for ceramic colors, refractories, and other uses.

An estimated 80% of U.S. zirconium metal consumption was used in commercial water-cooled nuclear reactors for fuel cladding and pressure tubes, 15% in naval nuclear reactors, and 5% for corrosion-resistant applications in the chemical industry and for photographic flashbulbs.

U.S. shipments of zirconium mill products declined about 10% in 1978 and 15% in

1979, mainly because of large inventories held by nuclear reactor manufacturers, and a combination of cancellations, deferrals, and delays in nuclear plant construction. However, demand for zirconium in the chemical process industry is expected to grow at a rate of 10% per year for the next 5 years.[7]

Zirconium compounds, natural and manufactured, were used in refractories, abrasives, polishes, glazes, enamels, welding rods, chemicals, and sandblasting. Zirconium chemicals were finding increasing application in the paint, textile, and pharmaceutical industries.

Hafnium metal consumption for control rods in nuclear reactors remains rather steady from year to year. Smaller but faster growing applications include use in refractory alloys, and in a newly developed hafnium-columbium carbide to substitute for tungsten carbide in cutting-tool alloys at a cost savings of 30% or more.[8] The use of hafnium foil in photographic flashbulbs was discontinued, since it was found that comparable results were obtainable using zirconium foil.

Table 3.—Estimated[1] consumption of zircon in the United States, by end use

(Short tons)

Use	1978	1979
Zircon refractories[2]	27,000	26,000
AZS refractories[3]	11,000	12,000
Zirconia[4] and AZ abrasives[5]	17,000	20,000
Alloys[6]	3,000	3,000
Foundry applications	72,000	75,000
Other[7]	34,000	32,000
Total	164,000	168,000

[1] Based on incomplete reported data.
[2] Dense and pressed zircon brick and shapes.
[3] Fused cast and bonded alumina-zirconia-silica-based refractories.
[4] Excludes oxide produced by zirconium metal producers.
[5] Alumina-zirconia-based abrasives.
[6] Excludes alloys above 90% zirconium.
[7] Includes chemicals, metallurgical-grade zirconium tetrachloride, sandblasting, welding rods, and miscellaneous uses.

Table 4.—Estimated[1] consumption of zirconium oxide[2] in the United States, by end use

(Short tons)

Use	1978	1979
AZ abrasives	5,000	6,000
AZS refractories[3]	2,000	2,500
Other refractories	1,600	2,000
Chemicals	600	700
Glazes, opacifiers, colors	800	800
Total	10,000	12,000

[1] Based on incomplete reported data.
[2] Excludes oxide produced by zirconium metal producers. Includes baddeleyite.
[3] Fused cast and bonded.

Table 5.—Yearend stocks of zirconium and hafnium materials

(Short tons)

Item	1977	1978	1979
Zircon concentrate held by dealers and consumers, excluding foundries	[r]21,775	[e]33,693	[e]32,314
Milled zircon held by dealers and consumers, excluding foundries	[r]4,277	[e]4,614	[e]5,217
Zirconium:[1]			
Oxide	[r]718	[e]931	[e]809
Sponge	[r]35	506	378
Ingot	68		
Scrap	113		
Alloys	244		
Refractories	[r]6,991	9,388	[e]9,125
Hafnium:[e]			
Sponge and crystal bar	40	40	40

[e] Estimate. [r] Revised.
[1] Excludes material held by zirconium sponge metal producers.

PRICES

The published yearend price for standard grade domestic zircon remained at $150 per ton in 1978 and 1979. Prices of zirconium oxides were either unchanged from 1977 levels, or were unlisted, for the last 2 years. The prices of zirconium chemicals were unchanged, except for zirconium hydride, which rose in price by about 40%. The listed price of zirconium powder was unchanged, and that of hafnium sponge was broadened to a range of $55-$110 per pound compared with the 1977 value of $75 per pound. Zirconium sponge prices increased by over 50% from the 1977 range of $5.50 to $9.00 per pound. Baddeleyite prices were slightly higher than in 1977. Listed prices for milled zircon were reduced about 50% below the 1977 price of $490-$495 per ton.

The U.S. equivalent of published prices for Australian zircon dropped from $68-$73 per short ton in December 1977 to $63-$68 per short ton in March 1978, rose briefly to $68-$78 per short ton in January 1979, then dropped to $51-$61 per short ton in February 1979, remaining at that level for the rest of that year. The published price of premium grade Australian zircon, however, was much firmer, falling only from $78-$83 per short ton in December 1977 to $73-$78 per short ton in March 1978, then rising to a range of $76-$86 per short ton in December 1978, remaining at that level throughout 1979. This increase in the differential between standard grade and premium grade zircon resulted from a continuing oversupply of standard grade material and a shortage of premium grade concentrate. An intermediate grade Australian zircon was quoted in 1979 at prices of $61-$77 per short ton.

Table 6.—Published prices of zirconium and hafnium materials

Specification of material	1978	1979
Zircon:		
Domestic, standard grade, f.o.b. Starke, Fla., bulk, per short ton[1]	$150.00	$150.00
Domestic, 75% minimum quantity zircon and aluminum silicates, Starke, Fla., bulk, per short ton[1]	90.00	99.00
Imported sand, containing 65% ZrO_2, f.o.b., bulk, per metric ton[2]	$75.00— 86.00	$55.00— 66.00
Domestic, granular, bags, bulk rail, from works, per short ton[3]	150.00	150.00
Domestic, milled, 200 and 325 mesh, rail, from works, bags, per short ton[3]	225.00	225.00
Baddeleyite, imported concentrate:[4]		
96% to 98% ZrO_2, minus 100-mesh, c.i.f. Atlantic ports, per pound	.33	.27— .40
99+% ZrO_2, minus 325-mesh, c.i.f. Atlantic ports, per pound	.69— .84	.75— .90
Zirconium oxide:[3]		
Powder, commercial-reactor grade, drums, from works, bags, per pound	NA	[5]3.00— 3.50
Chemically pure, white, ground, barrels or bags, works, per pound	2.22	2.22
Lump electric fused, bags, 500- to 1,999-pound lots, from works, per pound	NA	NA
Lump electric fused, bags, smaller lots, from works, per pound	NA	NA
Milled, bags, carlots, from works, per pound	NA	NA
Glass-polishing grade, ton lots, bags, 94% to 97% ZrO_2, from works, per pound	1.11	1.11
Opacifier grade, 3,300-pound lots, 85% to 90% ZrO_2, bags, per pound	.81	.81
Stabilized oxide, 100-pound bags, 91% ZrO_2, milled, per pound	1.57	1.57
Zirconium oxychloride: Crystal, cartons, 5-ton lots, from works, per pound[3]	.515	.515
Zirconium acetate solution:[3]		
13% ZrO_2, drums, carlots, 15-tons minimum, from works, per pound	.22	.22
22% ZrO_2, same basis, per pound	.38	.38
Zirconium hydride: Electronic grade, powder, drums, 100-pound lots, from works, per pound[3]	22.00	22.00
Zirconium:[6]		
Powder, per pound	70.00—100.00	70.00—100.00
Sponge, per pound	9.00— 15.00	9.00— 12.00
Sheets, strip, bars, per pound	18.00— 35.00	18.00— 35.00
Hafnium: Sponge, per pound	[6]55.00—110.00	[6]60.00— 90.00

NA Not available.

[1] E. I. du Pont de Nemours & Co. price list (effective Jan. 1, 1979) December 1978; and (effective Jan. 1, 1980) December 1979.

[2] Industrial Minerals (London). No. 135, December 1978, p. 65; No. 147, December 1979, p.77.

[3] Chemical Marketing Reporter. V. 215, No. 1, Jan. 1, 1979 (effective Dec. 29, 1978), p. 56; and v. 216, No. 27, Jan. 3, 1980 (effective Dec. 28, 1979), p.37.

[4] Ronson Metals Corp. Baddeleyite price lists. Jan. 1, 1979 and Jan. 1, 1980.

[5] Producer estimate.

[6] American Metal Market. V. 86, No. 251, Dec. 29, 1978, p. 8; and v. 87, No. 251, Dec. 28, 1979, p.5.

Table 7.—U.S. exports of zirconium ore and concentrate, by country

Destination	1978		1979	
	Pounds	Value	Pounds	Value
Argentina	--	--	30,000	$9,710
Brazil	1,483,125	$404,130	1,357,737	259,981
Canada	2,087,423	270,732	3,078,082	334,051
Chile	2,700	1,296	--	--
Colombia	794,864	242,694	1,477,538	390,571
Costa Rica	--	--	46,296	15,288
Ecuador	--	--	140,850	18,210
France	19,865	3,828	35,756	8,648
Germany, Federal Republic of	2,267,536	452,453	3,474,875	641,042
Greece	6,601	1,386	--	--
Guatemala	--	--	69,384	19,185
India	--	--	19,803	4,995
Israel	19,802	4,500	--	--
Italy	351,788	122,147	443,582	128,848
Japan	188,516	41,184	67,960	17,605
Korea, Republic of	--	--	111,202	25,970
Malaysia	6,601	2,970	6,601	2,970
Mexico	7,029,362	488,665	6,560,911	515,150
Netherlands	580,888	120,360	79,366	11,538
Peru	--	--	49,543	17,461
Portugal	10,000	1,600	--	--
Spain	6,600	1,254	--	--
Surinam	121,600	2,129	--	--
Sweden	--	--	19,028	1,370
Taiwan	4,800	1,728	16,167	1,164
United Kingdom	116,500	7,402	--	--
Venezuela	235,962	63,415	606,561	161,300
Yugoslavia	8,277	3,480	20,693	3,818
Total	15,342,810	2,237,353	17 711,935	2,588,875

Table 8.—U.S. exports of zirconium, by class and country

Country	1978		1979	
	Pounds	Value	Pounds	Value
Zirconium and zirconium alloys, wrought:				
Australia	86	$4,160	52	$2,404
Austria	64	1,134	--	--
Belgium-Luxembourg	118,398	4,106,319	54,896	2,519,236
Brazil	--	--	4	1,156
Canada	492,492	10,168,859	397,633	9,285,393
Denmark	175	3,646	--	--
France	7,636	155,019	37,326	886,456
Germany, Federal Republic of	286,980	4,637,783	66,068	1,388,155
Hong Kong	--	--	1,434	33,087
Israel	--	--	1,200	19,800
Italy	7	1,820	794	30,452
Japan	436,015	8,405,710	521,926	10,936,297
Korea, Republic of	181	3,412	2,022	89,445
Netherlands	36	738	1,101	31,795
Singapore	24	850	--	--
South Africa, Republic of	33	4,515	861	20,489
Sweden	77,494	2,055,684	32,413	2,865,888
Switzerland	--	--	239	5,384
Taiwan	2,143	76,502	--	--
United Kingdom	47,786	625,117	8,387	141,098
Venezuela	96	4,183	--	--
Total	1,469,646	30,255,451	1,126,356	28,256,535
Zirconium and zirconium alloys, unwrought and waste and scrap:				
Argentina	92	1,390	--	--
Belgium-Luxembourg	12,486	46,773	17,063	67,056
Brazil	158	8,102	156	3,039
Canada	11,214	232,206	15,008	284,524
Chile	--	--	29	1,764
France	8,953	87,864	61,717	283,401
Germany, Federal Republic of	72,476	637,829	57,207	254,516
India	22,077	158,954	--	--
Israel	--	--	72	1,652
Italy	8,466	26,379	11,355	27,500
Japan	220,531	1,411,269	103,792	1,447,439
Netherlands	302	2,868	66,730	158,880
Norway	--	--	6,615	30,760

Table 8.—U.S. exports of zirconium, by class and country —Continued

Country	1978		1979	
	Pounds	Value	Pounds	Value
Zirconium and zirconium alloys, unwrought and waste and scrap: —Continued				
Peru	762	$28,692	--	--
South Africa, Republic of	4,082	72,580	--	--
Sweden	109,517	598,081	135,828	$314,471
Switzerland	2,118	11,401	--	--
Taiwan	3,500	14,275	5,865	86,825
Thailand	101	960	2,021	19,208
Turkey	--	--	110	3,135
United Kingdom	113,582	1,260,371	242,734	2,771,311
Total	590,417	4,599,994	726,302	5,655,481

Table 9.—U.S. exports of zirconium oxide, by country

Country	1978		1979	
	Pounds	Value	Pounds	Value
Argentina	2,000	$2,225	69,071	$82,576
Australia	1,236	828	2,652	9,436
Belgium-Luxembourg	116,233	82,286	77,682	71,346
Bolivia	3,186	3,000	--	--
Brazil	32,200	38,646	23,160	47,525
Canada	1,177,582	844,972	701,170	1,465,656
Chile	--	--	2,200	1,980
El Salvador	--	--	1,095	1,018
France	654,607	1,611,564	34,654	79,105
Germany, Federal Republic of	940,700	169,004	960,925	301,174
Greece	9,559	6,347	5,270	8,703
Guatemala	--	--	3,402	3,780
Hong Kong	6,474	9,484	6,094	14,562
India	440	1,169	605	2,507
Israel	5,973	9,552	763	10,325
Italy	4,363	3,423	18,500	54,378
Japan	993,797	1,058,822	727,490	758,232
Korea, Republic of	1,745	1,169	1,788	29,115
Mexico	105,313	131,184	73,293	92,838
Netherlands	10,392	11,890	45,683	56,483
Netherlands Antilles	7,067	4,735	--	--
Norway	15,484	13,612	10,048	12,466
Panama	--	--	1,040	1,722
Peru	706	976	1,704	2,278
Singapore	256	594	630	1,718
South Africa, Republic of	--	--	1,300	8,575
Spain	2,157	3,204	3,714	5,740
Sweden	18,565	15,074	35,103	56,792
Switzerland	--	--	3,070	5,969
Taiwan	11,966	15,070	12,726	21,665
United Kingdom	102,271	84,090	155,955	181,742
Venezuela	20,733	16,612	--	--
Zaire	5,496	3,682	--	--
Total	4,250,501	4,143,214	2,980,787	3,384,406

Table 10.—U.S. imports for consumption of zirconium ores, by country

Country	1978		1979	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Australia	86,642	$14,731	101,144	$15,605
Austria[1]	22	3	124	15
Canada[1]	377	76	2,312	564
South Africa, Republic of[2]	3,928	396	7,262	779
Sweden[1]	40	3	--	--
Total	91,009	15,209	110,842	16,968

[1] Believed to be country of shipment rather than country of origin.
[2] In addition, imports of baddeleyite were estimated as follows: 1978-1,600 tons; 1979-1,600 tons.

Table 11.—U.S. imports for consumption of zirconium and hafnium

Class and Country	1978		1979	
	Pounds	Value	Pounds	Value
Zirconium, wrought:				
Canada	3,200	$76,901	25,736	$100,936
France	822,152	10,814,662	1,268,590	20,362,071
Gaza Strip	5,218	64,065	--	--
Germany, Federal Republic of	800	27,890	47	616
Italy	3	404	--	--
Japan	2,700	27,778	718	13,465
Netherlands	17	3,675	--	--
Sweden	60,334	123,174	--	--
Taiwan	--	--	30	6,766
Thailand	--	--	9	4,030
United Kingdom	12	712	4	2,212
Total	894,436	11,139,261	1,295,134	20,490,096
Zirconium, unwrought and waste and scrap:				
Canada	135,241	370,044	66,041	59,142
France	88	1,264	2,579	12,517
Germany, Federal Republic of	76,940	230,758	7,793	30,578
Japan	743,248	3,603,546	403,185	3,070,684
Netherlands	--	--	4,519	5,649
Sweden	18,419	21,092	32,439	46,580
Switzerland	--	--	9,307	14,686
Total	973,936	4,226,704	525,863	3,239,836
Zirconium alloys, unwrought:				
France	--	--	8,445	129,952
Germany, Federal Republic of	1,961	7,779	227	7,052
South Africa, Republic of	110,230	29,500	--	--
United Kingdom	--	--	3,233	9,840
Total	112,191	37,279	11,905	146,844
Zirconium oxide:				
Canada	--	--	220	572
France	55	953	--	--
Germany, Federal Republic of	270	21,754	1,759	41,352
Japan	3,637	25,546	5,528	40,469
South Africa, Republic of	44,093	12,000	89,556	21,494
Switzerland	86	7,212	244	4,930
United Kingdom	212,970	309,829	362,220	681,973
U.S.S.R	211,744	219,299	184,654	377,368
Total	472,855	596,593	644,181	1,168,158
Zirconium compounds:				
Belgium-Luxembourg	65	1,300	--	--
Canada	672	690	17,608	11,208
Denmark	--	--	1	400
France	99,427	70,606	99,366	85,297
Germany, Federal Republic of	4,603	51,643	10,084	80,046
Japan	220	4,329	13,669	13,669
Mexico	--	--	1,598	543
Netherlands	--	--	12,413	14,583
South Africa, Republic of	1,287,989	419,241	1,183,145	369,858
Sweden	51	658	--	--
Switzerland	77	5,100	--	--
United Kingdom	282,440	370,573	340,218	334,432
Total	1,675,544	924,142	1,678,092	909,986
Hafnium, unwrought and waste and scrap:				
Germany, Federal Republic of	--	--	115	4,683

WORLD REVIEW

Australia leads the world in the production of zircon, and produced a record 488,000 short tons in 1979. Australian zircon is recovered from sand mining operations along the eastern coast (42%) and in Western Australia (58%). Production of zircon on the east coast, where it is a coproduct of rutile, has been declining owing to lower grades and reserves coupled with persistent environmental problems. However, the decreased production on the east coast has been more than compensated for by increased output in Western Australia.

Zircon sand is also produced in Brazil,

Table 12.—Zirconium concentrate: World production, by country[1]

(Short tons)

Country	1976	1977	1978	1979[e]
Australia	[r]463,174	438,972	431,671	[2]487,601
Brazil	3,371	5,125	4,741	5,000
India[e]	11,400	11,800	11,400	11,000
Malaysia[3]	3,449	1,200	1,022	1,000
South Africa, Republic of	12,403	18,546	[e]40,000	90,000
Sri Lanka	11	[e]11	3,634	5,000
Thailand	61	60	28	30
United States	W	W	W	W
Total	[r]493,869	475,714	492,496	599,631

[e]Estimate. [r]Revised. W Withheld to avoid disclosing company proprietary data.

[1]No data are available on production, if any, within the centrally planned economy nations, nor is there any basis for the formulation of reliable estimates of output levels.

[2]Reported figure.

[3]Exports (production not officially reported; exports believed to closely approximate total output).

Mainland China, India, Malaysia, the Republic of South Africa, Sri Lanka, Thailand, and the U.S.S.R.

Baddeleyite is produced in the Republic of South Africa and in Brazil and also is found in East Africa, Sri Lanka, and the U.S.S.R.

In 1978 and 1979, consumption of zirconium ingot in market-economy countries was about 10.5 million pounds and 9.0 million pounds, respectively, of which approximately 7.5 and 7.0 million pounds was used for commercial nuclear powerplants. The total requirements of these countries for zirconium ingot are expected to reach 9 to 10 million pounds per year by 1985. By 1980 it was estimated that zirconium sponge production capacity would be 15 million pounds,[9] distributed approximately as follows: TWCA, 8 million pounds; Pechiney Ugine Kuhlmann Corp., at Jarrie, France, 3 million pounds; Western Zirconium, 3 million pounds; and Zirconium Industry Co. Ltd. and Nippon Mining Co., both of Japan, 0.5 million pounds each.

Australia.—Zircon continued to be in oversupply. Although producer stocks of zircon in Australia were greatly reduced in 1979, there was little improvement in the price of standard grade zircon. However, a shortage of premium grade zircon resulted in a divergence of price between the two grades, and it became apparent that there are also intermediate grades that can command intermediate prices.[10]

Some consolidation and merging of sand mining companies took place in 1978-79. The only large scale operators on the east coast in mid-1979 were Associated Minerals Consolidated, Ltd., Consolidated Rutile Ltd., Mineral Deposits, Ltd., and Rutile & Zircon Mines (Newcastle) Ltd.; and on the west coast, Associated Minerals Consolidated, Westralian Sands Ltd., Cable Sands Pty. Ltd., Allied Eneabba Pty. Ltd., and Jennings Mining Ltd.[11] In April 1979 it was reported that Du Pont would become a majority shareholder in Allied Eneabba,[12] and in September 1979 CGFA and AMC announced that they had reached agreement to purchase Jennings Industries mineral sands operations at Eneabba and Geraldton.[13]

Murphyores Holdings Ltd. was reportedly planning a new $A20-million operation near Gladstone in Queensland to produce about 50,000 tons of rutile and zircon, and 140,000 tons of ilmenite per year. Murphyores was also reported in the Australian press to be exerting pressure on the Federal Government to reverse its controversial decision to stop sand mining on Fraser Island.[14]

NL Industries, Inc. late in 1979 sold its subsidiary, Titanium Alloy Manufacturing Co. Pty. Ltd. (Tamco), to Utah Mining Australia, Ltd. Tamco's principal assets included an 85% interest in Mineral Deposits, Ltd., a producer of rutile and zircon concentrates and a manufacturer of mineral processing systems.

Early in 1978, Dillingham Corp. announced its withdrawal from mineral sand mining in Australia, stating that the New South Wales Government's action in banning future mining in areas designated as national parks, combined with the Federal Government's withdrawal of export licenses for Fraser Island mineral concentrates at the end of 1976, made it impossible for Dillingham to continue mineral sands mining in Australia.

Canada.—Great Canadian Oil Sands Ltd. (GCOS) and Syncrude Canada Ltd. extract a total of about 95 million short tons of tar sands annually from which 41,000 short tons per year of zircon can be produced. The

Alberta Government was working with GCOS and Syncrude on a beneficiation process for the recovery of zircon and other heavy minerals. Canadian Titanium Pigments Ltd. reportedly continued to be interested in the recovery of zircon for sale to the foundry and abrasives industries, as well as in the recovery of titanium minerals for use in the pigment industry.[15]

Egypt.—Zircon makes up about 3% of the potentially economic minerals of Egyptian Mediterranean coast deposits. The reasonably assured resources of zircon in the top meter of black sand deposits are reportedly 849,000 tons, while the estimated additional resources to 20 meters depth are estimated at 16.2 million tons.

Japan.—In 1979 Nippon Mining Co. was to modify its zirconium plant at Toda, Saitama Prefecture, to produce zirconium metal from zircon sand containing hafnium by means of a continuous reduction-separation method. Annual production capacity was to be 300 tons of nuclear-grade metal, with another plant of 1,000-ton-per-year capacity to be built and in operation by early 1982.

Zirconium Industry Co., Ltd., which has been producing zirconium metal from TWCA zirconium oxide, reportedly has an annual metal production capacity of about 300 tons per year.

Sierra Leone.—Production of rutile, ilmenite, and zircon by Sierra Rutile Ltd. began in 1979. Shipments in 1979 were expected to be about 35% of the planned full annual capacity of 110,000 tons of rutile, 27,000 tons of ilmenite, and 11,000 tons of zircon.

South Africa, Republic of.—Production of zircon, rutile, and high titanium slag by Richards Bay Minerals (RBM) in Natal increased gradually, and in 1979 was estimated at 60% to 75% of planned full capacity of 127,000 tons of zircon, 62,000 tons of rutile, and 440,000 tons of 85% TiO_2 slag. The availability of standard grade zircon from South Africa helped to insure that this material remained in oversupply on world markets. At the same time, production of RBM's higher quality ceramic grade zircon has helped to alleviate a shortage of premium grade zircon.[16] Full capacity production is expected to be reached in 1980.

TECHNOLOGY

The Bureau of Mines, as part of an effort to maximize minerals and metals recovery from domestic resources, investigated the feasibility of recovering heavy minerals, including zircon, from sand and gravel, placer gold, and industrial mineral operations in northern California. Sand samples from about 50 locations were treated by gravity separation to yield heavy mineral concentrates. From five of these concentrates individual zircon, ilmenite, magnetite, platinum-group metals, thoria, and silica products were prepared by magnetic, high-tension, and flotation methods. It was concluded that successful recovery of byproduct minerals will depend on the development of markets for the mineral concentrates and incorporation of high-capacity concentrating equipment into the sand-washing circuit of the plants to prepare heavy mineral concentrates. A plant utilizing relatively high-cost equipment to produce marketable mineral concentrates could be built in a central location to treat heavy mineral concentrates obtained from several individual sand and gravel operations.[17]

The Bureau was continuing work on the use of zircon as a molding material for casting titanium and zirconium, with the object of replacing the rammed-graphite process for casting these materials with a lower cost process that consumes less energy, produces less waste, and causes no air pollution. A Bureau report published in 1977 described static casting of small titanium and zirconium shapes.[18] Current work has extended the use of zircon sand molds to making larger castings, including some that could not be cast successfully by commercial foundries in a rammed graphite mold. Other Bureau research being carried out included the development of improved zirconium-hafnium separation technology, and preparation of a calcia-stabilized, high-zirconia castable composition.

In a research program conducted by Syncrude Canada Ltd., the crude tailings stream from hot-water extraction processing of tar sand was upgraded using conventional concentrating equipment to produce good quality zircon and titanium mineral products. An economic evaluation led to the conclusion that a market for Syncrude zircon may become available after 1980.[19]

An article on the use of tin in Zircaloys for nuclear reactors discussed the properties that make zirconium ideal for such service, particularly for the cladding of the uranium dioxide fuel used in water-cooled reactors.[20] The manufacture, nondestructive testing, and mechanical properties of zirconium alloy pressure tubes were discussed in an article on the use of such tubes in Candu power reactors, which exploit the advantage of using natural uranium fuel. The tubing wall thickness was reduced to lower the fueling costs by changing from Zircaloy-2 to the stronger Zr-2.5-weight-percent Nb alloy, which in 1979 was standard for pressure tubes in Candu pressurized hot-water reactors.[21]

An article was published which discussed the use of magnesium in the production of zirconium metal. At the level of TWCA production of 600,000 pounds per month in mid-1978, about 660,000 pounds per month of magnesium was consumed, of which about one quarter was internally recycled.[22]

Australian foundry trials of zircon-silica sand mixtures containing 25% to 70% zircon have resulted in a reduced number of castings rejects, improved surface finish, and economic advantages. The AMC mill at Eneabba produces an air table tailings containing 50% to 70% zircon sand with the remainder being predominantly silica. A number of trials resulted in the acceptance of these tailings by many Western Australian foundries as an additive to silica sand and as a straight molding medium.[23]

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Minor Metals

By Staff, Section of Nonferrous Metals

CONTENTS

	Page
Arsenic	1033
Cesium and rubidium	1037
Germanium	1038
Indium	1040
Radium	1042
Scandium	1042
Selenium	1043
Tellurium	1046
Thallium	1049

ARSENIC[1]

Demand for arsenic trioxide exceeded supply in 1978 and 1979, and the major domestic and foreign producers allocated available supplies to customers. Major demand has been from the cotton-growing and wood-preserving industries.

Ample supplies of arsenic metal produced in the United States and Sweden were available in 1978 and 1979. Major demand for metal was from the automobile battery industry in Japan, Europe, and the United States.

Legislation and Government Programs.—The Occupational Safety and Health Administration (OSHA), promulgated the final standard on the occupational exposure to inorganic arsenic, effective August 1, 1978.[2] The need for the standard was a result of OSHA's conclusion that inorganic arsenic is a human carcinogen. The purpose of the standard was to minimize the incidence of lung cancer among workers exposed to inorganic arsenic. The maximum exposure to arsenic was lowered from the previous ceiling of 500 micrograms per cubic meter of air to 10 micrograms per cubic meter over an 8-hour time period. OSHA had originally recommended a ceiling limit of 4 micrograms per cubic meter in January 1975. Provisions of the new standard require exposed employees to wear respirators and undergo continuous medical monitoring. Other provisions establish regulated areas limited to authorized employees and require the construction of special lunchroom and worker hygiene facilities and the posting of signs and labels warning of the presence of arsenic. The new arsenic standard will have a significant economic impact on copper, zinc, gold, and lead smelters as well as consumers of arsenic trioxide. A number of copper companies have joined together to contest the standard in court. However, measures to comply with the standard have been initiated by ASARCO Incorporated at its Tacoma, Wash. plant.

Under provisions of the Federal Insecticide, Fungicide, and Rodenticide Act, the Environmental Protection Agency (EPA) has authority to regulate the manufacture of wood preservatives. On October 18, 1978, EPA issued a notice of Rebuttable Presumption Against Registration (RPAR). RPAR requires manufacturers of wood preservatives, including creosote, pentachlorophenol (PCP), and arsenical compounds to submit to EPA any additional information regarding any adverse effects that come to the manufacturer's attention at any time.[3] Issuance of this RPAR means that adverse effects that can be associated with the use of inorganic arsenic have been identified and that a public review process of its risks and benefits will begin. The RPAR does not mean that EPA has decided to cancel or suspend the pesticide's registration.

In May 1979, EPA announced that the arsenical chemical, 10, 10-oxybisphenoarsine (OBPA), widely used in plastic products, was found to be noncarcinogenic.

Domestic Production.—Arsenic trioxide and arsenic metal were produced only at ASARCO's Tacoma, Wash., copper smelter. Production data cannot be published.

ASARCO processed arsenic residues and high-arsenic copper concentrates from both imported and domestic sources. In the last 5 years, environmental restrictions and regulations have limited the amount of arsenic produced and used.

Consumption and Uses.—Apparent consumption of arsenic as metal and in compounds increased in the United States in 1978. Major uses of arsenic compounds were in the manufacture of agricultural chemicals (herbicides and plant desiccants), 70%; industrial chemicals (wood preservatives and mineral flotation reagents), 20%; glass and glassware, 5%; and other uses (feed additives and pharmaceuticals), 2%. The most important commercial arsenic compound is arsenic trioxide. Major uses of the metal were as an alloying agent in nonferrous alloys (lead- and copper-based) and for electronic applications. These uses accounted for 3% of consumption.

Arsenical wood preservatives include chromated copper arsenate (CCA) and fluor chrome arsenate phenol (FCAP). Usage of CCA increased from 12,389 tons in 1977 to 12,494 tons in 1978, the latest year for which data are available. Usage of FCAP was withheld in 1977 and was 112 tons in 1978.

Demand for arsenic in cotton plant desiccants (arsenic acid) and herbicides (MSMA and DSMA) increased in 1978 and 1979. Most of the desiccants and herbicides were consumed in Texas and Oklahoma. These two States produced 5.9 million bales of cotton in 1977, 4.2 million bales in 1978, and 6.2 million bales in 1979.[4]

Prices.—Arsenic trioxide, minimum 95%, was sold in quantities varying between 200-pound drums and 120,000-pound carloads. In addition, arsenic metal, 99.5% minimum, was sold in 200-pound drums.

The tabulation below indicates that prices of arsenic trioxide rose substantially in 1978 relative to those of 1977. Prices in 1979 increased slightly over those of 1978. Part of the sharp price increases in 1978 was reportedly the result of higher processing costs associated with tighter OSHA regulations on the manufacture of arsenic.

	Prices of arsenic (cents per pound, yearend)		
	1977	1978	1979
Trioxide, domestic, 95% As_2O_3, f.o.b. Tacoma, Wash	13.1	23.25	24.25
Trioxide, Mexican, 99.13% As_2O_3, f.o.b. Laredo, Tex	18	27	30
Trioxide, Imports	20-21	28-32	32
Metal, domestic, 99.5% As	190	190	190

Table 1.—U.S. imports for consumption of arsenic trioxide (As_2O_3) content, by country

Country	1977		1978		1979	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Belgium-Luxembourg	44	$13	189	$48	184	$50
Canada	22	10	136	34	277	80
France	1,352	420	5,077	1,844	3,242	1,376
Germany, Federal Republic of	1	4	1	6	6	15
Japan	140	57	(1)	1	--	--
Mexico	3,089	1,009	2,603	1,064	3,125	1,799
Peru	--	--	--	--	477	148
Sweden	1,323	443	2,281	764	5,014	2,086
United Kingdom	10	6	19	9	(1)	8
Total	5,981	1,962	10,306	3,770	12,325	5,562

[1] Less than 1/2 unit.

Table 2.—U.S. imports for consumption of arsenicals, by class

Class	1977 Quantity (short tons)	1977 Value (thousands)	1978 Quantity (short tons)	1978 Value (thousands)	1979 Quantity (short tons)	1979 Value (thousands)
Arsenic trioxide (As_2O_3)	5,981	$1,962	10,306	$3,770	12,325	$5,562
Metallic arsenic	357	1,381	369	1,622	405	1,881
Sulfide	--	--	(1)	1	39	112
Sodium arsenate	1	1	(1)	3	1	3
Arsenic acid	382	180	565	260	176	94
Arsenic compounds n.e.c.	1,109	686	473	262	1	76

[1] Less than 1/2 unit.

Table 3.—U.S. imports for consumption of arsenicals, by country

(Short tons)

Country of origin	Metal (632.04) 1978	Metal (632.04) 1979	Compounds (417.64) 1978	Compounds (417.64) 1979	Acid (416.05) 1978	Acid (416.05) 1979
Belgium-Luxembourg	--	--	(1)	(1)	--	--
Canada	5	11	--	--	4	--
France	--	--	287	(1)	--	--
Germany, Federal Republic of	1	(1)	38	(1)	--	--
Japan	2	(1)	(1)	(1)	--	--
Mexico	--	--	--	--	430	68
Netherlands	--	(1)	(1)	--	--	--
Sweden	361	394	--	--	--	--
United Kingdom	(1)	(1)	148	(1)	131	108
Total	369	405	473	1	565	176

[1] Less than 1/2 unit.

Foreign Trade.—Imports of arsenic trioxide have increased about threefold since their low point in 1976. Sweden regained its traditional position as the principal U.S. supplier of trioxide in 1979, followed by France and Mexico. In 1977 and 1978, Sweden was the third largest U.S. supplier.

In addition to the commodities listed in Table 2, less than 1 ton of arsenic sulfide (417.6) was imported from the United Kingdom, 1 ton of sodium arsenate (420.7) was imported from the Federal Republic of Germany, and 4 tons of sheep dip or sodium arsenite (493.75) was imported from New Zealand in 1978. For the year 1979, 39 tons of arsenic sulfide was imported; 22 tons from Canada, 17 tons from Belgium-Luxembourg, and less than 1 ton from the Federal Republic of Germany. Less than 1 ton of sodium arsenate was imported from the Federal Republic of Germany, the Netherlands, and the United Kingdom. One ton of sheep dip was imported from New Zealand in 1979.

Significant revisions of tariff rates on many mineral commodities including arsenic resulted from an agreement reached in 1979 in Tokyo between the developed nations of the world. The tariff rate for arsenic metal (TSUS 632.04) and other arsenic compounds (TSUS 417.64) were scheduled to be reduced in gradual stages beginning Jan. 1, 1980, and ending Jan. 1, 1987. The following tabulation indicates scheduled changes in the U.S. tariff rates for arsenic materials.

Item	Number	Most Favored Nation (MFN) 1/1/79	Most Favored Nation (MFN) 1/1/80	Most Favored Nation (MFN) 1/1/87
Metal	632.04	2 cents per pound	1.8 cents per pound	Free.
Trioxide and sulfide	417.62, 417.60	Free	Free	Free.
Other compounds	417.64	5% ad valorem	4.8% ad valorem	3.7% ad valorem.

The tariff rate charged to Non-Most-Favored-Nations remained unchanged at 6 cents per pound for metal, free for trioxide and sulfide, and 25% ad valorem for other compounds.

World Review.—Demand for arsenic trioxide exceeded supply in 1978 and 1979, and the United States, Sweden, and Mexico allocated available supplies to customers.

France.—Société Minière et Métallurgique de Peñarroya (Peñarroya) produced 99.5% arsenic trioxide as a byproduct of imported Moroccan cobalt; and Mines et Produits Chimiques de Salsigne (Salsigne) produced 96% to 98% arsenic trioxide as a gold and silver byproduct.

Philippines.—Lepanto Consolidated Ltd. plans to construct a 18,000-metric-ton-per-year copper concentrate roasting plant. The plant will produce arsenic trioxide and copper calcines.

South-West Africa, Territory of.—Tsumeb Corp. Ltd. produced arsenic trioxide as a byproduct of lead and copper ore. Lower lead production has resulted in declining rates of arsenic production since 1974 and 1975.

Table 4.—White arsenic (arsenic trioxide):[1] World production, by country

(Short tons)

Country[2]	1976	1977	1978[p]	1979[e]
France	8,002	[r] [e]8,000	[e]8,000	8,000
Germany, Federal Republic of[e]	400	400	400	400
Japan	66	--	NA	NA
Korea, Republic of	[r]782	541	604	650
Mexico	[r]6,062	6,332	6,884	7,000
Peru	[r]879	1,507	1,386	1,500
Portugal	306	245	220	240
South-West Africa, Territory of[3]	[r]5,646	2,882	2,647	2,500
Sweden[4]	[r]7,411	7,443	7,372	7,400
U.S.S.R.[e]	8,200	8,300	8,400	8,500
United States	W	W	W	W
Total	[r]37,754	35,650	35,913	36,190

[e]Estimate. [p]Preliminary. [r]Revised. NA Not available. W Withheld to avoid disclosing company proprietary data.

[1]Including calculated arsenic trioxide equivalent of output of elemental arsenic and arsenic compounds other than white arsenic, where inclusion of such materials would not duplicate reported white arsenic production.

[2]In addition to the countries listed, Austria, Belgium, Mainland China, Czechoslovakia, the German Democratic Republic, Finland, Hungary, Southern Rhodesia, the United Kingdom, and Yugoslavia have produced arsenic and/or arsenic compounds in previous years, but information is inadequate to make reliable estimates of output levels.

[3]Output of Tsumeb Corp. Ltd. only.

[4]Output of white arsenic for sale plus the white arsenic equivalent of the output of metallic arsenic for sale.

Technology.—Most of the technological effort in arsenic has been directed toward removing arsenic as a contaminant from other metals and stack gases. Research was conducted at the U.S. Bureau of Mines Salt Lake City Research Center on devising methods for the removal of arsenic from arsenical smelter flue dusts and for the recovery of byproduct metals from the dust. The smelter flue dusts were dissolved in sulfuric acid. Arsenic in the acid leach solutions was decreased to less than 10 parts per million by precipitation with ferric iron and lime, reaction with metallic zinc, and precipitation with hydrogen sulfide. Research was continuing to reduce the quantities of sulfuric acid consumed.

In a study performed by the Bureau of Mines Avondale Research Center, the concentration of arsenic in combustible municipal solid waste (MSW) was found to be similar to the concentration of arsenic found in coals from Illinois and Eastern U.S. coalfields.[5]

In a report prepared for the Department of Energy by the Pacific Northwest Laboratory, Division of Battelle Memorial Institute, both arsenic and gallium were listed along with five other elements as showing potentially serious material constraints if selected for large-scale use in a gallium arsenide solar electric cell.[6] Gallium arsenide solar cells could, theoretically, achieve efficiencies in excess of 25%, compared with the cheaper, but less efficient (20%, theoretical), silicon cells. The Battelle report presents a detailed state-of-the-art description of many different solar cell construction prototypes.

CESIUM AND RUBIDIUM[7]

Domestic Production.—There was no domestic production of cesium- or rubidium-bearing minerals in 1978 or 1979. Cesium and its compounds were produced from imported cesium ore (pollucite), and rubidium and its compounds were produced from imported lepidolite. Compared with the 1977 level, cesium and rubidium compound production decreased slightly in 1978 but increased about 50% in 1979.

In May 1978, Kawecki Berylco Industries, Inc. (KBI), Revere, Pa., a major producer of cesium and rubidium metal and compounds, became a wholly owned subsidiary of Cabot Corp. Other possible sources of cesium and rubidium metal and compounds included Callery Chemical Co., Callery, Pa., Great Western Inorganics Inc., Golden, Colo., and Kerr-McGee Chemical Corp., Trona, Calif.

Consumption and Uses.—Quantitative data pertaining to consumption and end use distribution of cesium and rubidium metal and compounds were not available. These materials found commercial applications in the manufacture of pharmaceuticals, ultracentrifuge separation of organic compounds, and in electronic apparatus such as scintillation counters, photomultiplier tubes, and photoelectric cells. Cesium, rubidium, and their compounds can be substituted for each other in some end uses. Cesium metal and compounds have been used in experimental magnetohydrodynamic (MHD) power generators.

Prices.—The yearend 1979 American Metal Market quotation for cesium metal, 99+% purity, was $225 per pound. At yearend the nominal price quoted in the Metal Bulletin for pollucite concentrates containing a minimum of 24% Cs_2O, f.o.b. source, was $12.40 to to $13 per metric ton unit (22.046 pounds) of Cs_2O. Rubidium metal, 99.5% purity, according to industry sources, was priced at $250 to $300 per pound. According to industry sources, prices for cesium and rubidium compounds remained the same in 1978 and 1979.

Table 5.—Prices of selected cesium and rubidium compounds in 1978 and 1979

Item	Base price per pound[1]	
	Technical grade	High-purity grade
Cesium bromide	$29	$67
Cesium carbonate	29	67
Cesium chloride	31	70
Cesium fluoride	37	77
Cesium hydroxide	35	75
Rubidium carbonate	54	86
Rubidium chloride	55	87
Rubidium fluoride	60	94
Rubidium hydroxide	61	94

[1] Price is for quantities of less than 100 pounds, f.o.b. Revere, Pa., excluding packaging costs.

Source: Kawecki Berylco Industries, Inc.

Foreign Trade.—Canada reported exporting 280 short tons of pollucite concentrate to the United States in 1978 and none in 1979. Import data showed that 35,008 pounds of rubidium in unspecified form was received from Canada in 1978 and none in 1979.

The United States established new tariff rates for cesium and rubidium, with separate rates for Most Favored Nation (MFN) and Non-Most Favored Nation (Non-MFN) statuses. The following tabulation indicates the scheduled changes.

Item	Number	MFN 1/1/80	MFN 1/1/87	Non-MFN 1/1/80
Ore and concentrate	601.66	Free	Free	Free.
Cesium	415.10	8.1% ad valorem	5.3% ad valorem	25% ad valorem.
Cesium chloride	418.50	5.8% ad valorem	4% ad valorem	25% ad valorem.
Other cesium compounds	418.52	4.9% ad valorem	4% ad valorem	25% ad valorem.
Rubidium	415.40	4.8% ad valorem	3.7% ad valorem	25% ad valorem.
Rubidium compounds	423.00	4.8% ad valorem	3.7% ad valorem	25% ad valorem.

Table 6.—U.S. imports for consumption of cesium compounds in 1978 and 1979, by country

Country	1978				1979			
	Cesium chloride		Cesium compounds, n.s.p.f.		Cesium chloride		Cesium compounds, n.s.p.f.	
	Quantity (pounds)	Value	Quantity (pounds)	Value	Quantity (pounds)	Value	Quantity (pounds)	Value
Canada	--	--	--	--	45	$1,853	--	--
Germany, Federal Republic of	3,124	$192,063	9,523	$380,555	4,071	243,171	18,030	$648,447
United Kingdom	659	25,886	1	252	999	33,353	37	1,564
Total	3,783	217,949	9,524	380,807	5,115	278,377	18,067	650,011

World Review.—In late 1978, International Chemalloy Corporation sold its 50.1% interest in Tantalum Mining Corp. of Canada, Ltd. (TANCO) under arrangements whereby Hudson Bay Mining and Smelting Co., Limited, of Canada and KBI of New York each became owners of 37.5% of TANCO. The Manitoba Development Corporation, the investment agency of the Manitoba Government, holds the remaining 25% interest. A description of the deposit at Bernic Lake, Manitoba, published in February 1979, reported reserves of 350,000 tons of ore containing 23.3% Cs_2O.[8]

Technology.—A U.S. Department of Energy-sponsored project to test a biomass-to-ethanol scheme using radiation (possibly from Cs-137 from nuclear plant wastes) instead of fermentation was conducted at the University of Southern Mississippi. Production and commercial feasibility of the process had not yet been determined, but investigators regarded it as theoretically sound and promising for widespread application.

GERMANIUM[9]

Consumption of germanium in infrared electro-optic systems continued to expand during 1978 and 1979. The trend away from the use of germanium in some semiconductor applications continued during 1978 and, to a lesser extent, during 1979. Demand for germanium in other traditional or experimental applications continued at about the same level as in previous years.

Domestic Production.—Eagle-Picher Industries, Inc., at Quapaw, Okla., was the sole domestic producer of primary germanium. Most of the output was extracted from stockpiled smelter residues produced in past years from the concentrates derived from zinc-mining operations in the Kansas-Missouri-Oklahoma district. New scrap generated during the manufacture of electronic devices and electro-optical components was recycled.

Kawecki Berylco Industries, Inc., Revere, Pa., and Atomergic Chemetals Co., Plainview, N. Y., produced germanium from domestic secondary materials as well as imported metal, oxide, and scrap.

An estimated 19,200 kilograms of germanium was produced from domestic primary and secondary sources during 1978, and during 1979 production was estimated to be 23,000 kilograms. Based on the U.S. producer price for refined germanium the approximate combined value of production in 1978 and 1979 was over $13 million.

Consumption and Uses.—Germanium usage in infrared optical systems increased substantially during 1978 and 1979. Forward-looking infrared (FLIR) detection devices, which usually employ several large germanium lenses, are finding increasing application in various military guidance systems. During 1978 and 1979, the demand for germanium as a substrate upon which gallium arsenide phosphide is deposited to form an essential part of light-emitting diodes (LED) increased slightly over the 1977 level. However, the demand for LED displays was increasingly supplanted by the use of liquid-crystal displays (LCD). As less expensive, more versatile silicon devices were developed, the production of germanium semiconductors for use in transistors and signal diodes continued to decline throughout 1978. However, during 1979, increased demand for silicon semiconductor devices together with spot shortages of polysilicon resulted in a modest increase in the demand for more expensive substitute germanium. In April 1978, the Delco Electronic Division of General Motors Corp. discontinued the use of germanium devices in automobile radios and other products. In mid-1979, Texas Instruments Incorporated sold its germanium transistor interests to Germanium Power Devices Corp. of Andover, Mass.

The development of glass-fiber light guides for long-distance telecommunications was further advanced by the use of high-index germania-core fibers, which were found to achieve the lowest practical attenuation of any materials tested thus far. The fiber optic system, which replaces conventional wire conductors, provides a very compact, inexpensive, short-circuit-free transmission medium that is not susceptible to distortion by an electromagnetic field and that cannot be tapped using currently available technology. As a compact transmission medium, the carrying capacity of existing conduits for metallic wire could be expanded many-fold through conversion to a fiber optic system. Germanium was also used in highly sensitive single-crystal gamma-radiation detectors, glass microscope lenses, petroleum and petrochemical catalysts, fluorescent lamp phosphors, and special-purpose alloys.

The estimated consumption pattern for various end uses of germanium during the 2-year period was about 50% in instruments and optics, 45% in electronics, and 5% for other uses including research.

Prices.—Effective December 1, 1978, the price of germanium metal was increased from \$316 per kilogram to \$348. Electronic-grade germanium dioxide prices rose from \$167.50 to \$195.50 per kilogram. New York dealer prices for imported metal and dioxide underwent three consecutive increases so that by November 2, 1978, the price stood at \$412 per kilogram for metal and \$218.50 per kilogram for dioxide. During 1979, the influence of the continued increase in demand for germanium for infrared applications, spot substitution of germanium for silicon in semiconductors, the necessity to recover germanium from ever-lower-grade raw materials, increasing world energy costs, and fluctuations in international currency exchange rates, resulted in numerous price adjustments during the year. By year-end 1979, the U.S. producer prices of germanium metal and dioxide stood at \$521.50 and \$307.25 per kilogram, respectively. New York dealer prices for imported germanium closed the year at \$497.50 per kilogram for germanium metal and \$269.50 per kilogram for dioxide.

Table 7.—U.S. imports for consumption of germanium in 1978 and 1979, by country

Country	1978		1979	
	Quantity (kilograms)	Value	Quantity (kilograms)	Value
Unwrought and waste and scrap:				
Belgium-Luxembourg	520	\$759,671	961	\$985,102
Denmark	306	25,474	--	--
Germany, Federal Republic of	640	144,934	300	71,535
Italy	142	18,125	--	--
New Zealand	100	19,204	--	--
Switzerland	3	2,334	2,600	144,554
United Kingdom	344	30,451	--	--
U.S.S.R	576	117,092	--	--
Total	2,631	1,117,285	3,861	1,201,191
Wrought:				
Belgium-Luxembourg	25	16,670	166	93,702
France	--	--	1	600
Germany, Federal Republic of	--	--	1	743
Total	25	16,670	168	95,045

World Review.—As a byproduct of base-metal mining, mainly zinc, primary germanium supplies were dependent upon the rate of production and recovery of the host metal. Austria and the Federal Republic of Germany, France, Italy, and the United States were the major identified sources of germanium-bearing raw materials. The U.S.S.R. and possibly Japan recovered germanium from internal primary sources. The largest reserves of germanium were located in the Shaba (formerly Katanga) Province of Zaire, and germanium-bearing concentrates and smelter residues from that country have traditionally been refined in Belgium by Metallurgie Hoboken-Overpelt, S.A. However, due to recent political difficulties in Zaire, no germanium-bearing material has been reported to have moved from Zaire to Belgium over the past several years. The Belgian refinery also relied upon material derived from mines in Italy, France, and other European countries as well as stockpiled material from Zaire. Other germanium refineries were located in the Federal Republic of Germany, France, Italy, Japan, the U.S.S.R., and the United States.

World production of refined germanium during 1978 and 1979 was estimated to have been 99,000 and 109,000 kilograms, respectively. France and Italy combined produced over 27,000 kilograms during 1978 and an estimated 26,000 to 33,000 kilograms during 1979. In 1978, Austria reported that 4,270 kilograms of germanium were contained in zinc concentrates produced during the year.

Technology.—A niobium-germanium-coated superconducting tape of copper or nickel was developed in conjunction with research aimed at achieving less expensive and more energy-efficient methods of transmitting large blocks of electrical power. The tape, which would operate in a cryogenic cable, has been fabricated in experimental lengths of up to 20 meters using chemical vapor deposition. No problems were foreseen in producing longer lengths for commercial applications.[10]

A new pyrometallurgical process was developed and patented for the recovery and purification of germanium from residues obtained during the controlled distillation and recovery of zinc from zinc ore. The resultant germanium product was of high purity, especially with respect to arsenic.[11]

The addition of lead germanate to the barium titanate used in ceramic capacitors was found to result in improved electrical characteristics, to simplify and increase the energy efficiency of the manufacturing process, and to allow the use of less expensive electrode materials.[12]

INDIUM[13]

Domestic Production.—Indium was produced by ASARCO Incorporated at its Denver, Colo., plant, by Indium Corp. of America in Utica, N.Y., and by NJZ Alloys, Inc., a partnership of the New Jersey Zinc Co. and Indium Corp. The partnership produced indium at the Palmerton, Pa., plant of New Jersey Zinc, with further refining and marketing provided by Indium Corp. Domestic production in 1978 and 1979 was withheld to avoid disclosing company proprietary information, but remained about the same as in 1977. Small amounts of secondary indium were available from specialty-metal-recycling firms.

Consumption and Uses.—Indium consumption increased somewhat in 1978 and 1979 compared with 1977 levels. Despite sharply rising prices, the metal continued to find application in a variety of uses and research studies involving possible future uses, particularly for solar cells, remained active. Significant increases were registered in the use of indium for nuclear control rods. Estimated consumption patterns for indium were instruments, 30%; solders, alloys, and coatings, 40%; electronic components, 10%; research and other uses, 20%.

Stocks.—Producer stocks remained relatively constant throughout the 1978-79 period.

Price.—The price of indium metal approximately doubled in the 1978-79 period. The price in January 1978 was $8.50 to $10.00 per troy ounce; declined in March 1978 to $7.75 to $8.50 per troy ounce, but after a series of upward moves, reached $10.50 per troy ounce by the end of 1978. By February 1979, the price rose to $10.50 to $11.00 per troy ounce. A series of steady increases led to a price of $13.50 per troy ounce by June 1979, and by yearend, the price reached $18.50 per troy ounce. The price increases were attributed to lower indium content in residues at a time of generally increasing demand.

Foreign Trade.—Imports of indium declined in 1978, but rose in 1979 to approximately the 1977 levels. Imports remained well below the high levels of the 1970-74

Table 8.—U.S. imports for consumption of indium, by country

(Thousand troy ounces and thousand dollars)

Country	1977		1978		1979	
	Quantity	Value	Quantity	Value	Quantity	Value
Unwrought and waste and scrap:						
Belgium-Luxembourg	4	22	33	432	124	1,504
Canada	60	524	25	196	36	458
Germany, Federal Republic of	19	186	23	222	16	176
Japan	24	175	24	268	3	24
Mexico	--	--	--	--	3	4
Netherlands	20	137	3	39	3	36
Peru	89	865	71	589	90	1,172
United Kingdom	70	294	25	303	7	219
Total	286	2,203	204	2,049	282	3,593
Wrought:						
Belgium-Luxembourg	--	--	--	--	1	13
Canada	(1)	2	--	--	(1)	6
France	(1)	1	--	--	--	--
Germany, Federal Republic of	--	--	(1)	2	1	7
Netherlands	--	--	(1)	1	(1)	1
Peru	5	43	2	15	9	137
United Kingdom	(1)	5	(1)	18	1	22
Total	5	51	2	36	12	186

[1] Less than 1/2 unit.

period. The 1979 value of indium imports, at $3.6 million was the highest in recent years, primarily reflecting higher indium prices.

In 1978-79 the duty on unwrought, waste and scrap indium remained at 5% ad valorem for the Most Favored Nations. Duties on waste and scrap were suspended until June 30, 1981, by Public Law 95-508. The duty on wrought indium was 9%. Statutory duties for the U.S.S.R. and the German Democratic Republic were 25% ad valorem on unwrought and 45% ad valorem of wrought metal.

Starting in 1980, changes were effected in the tariff for indium as follows:

Item	Number	MFN		Non-MFN
		1/1/80	1/1/87	1/1/80
Unwrought and waste and scrap	628.45	2% ad valorem	Free	25% ad valorem.
Wrought	628.50	8.3% ad valorem	3.6% ad valorem	45% ad valorem.
Compounds	423.96	4.4% ad valorem	Free	25% ad valorem.

World Review.—A strengthened production pattern characterized several of the main world indium producers in 1978 and 1979 compared with 1977. Cominco Ltd., traditionally a major factor among world producers and Canada's only indium producer, significantly expanded output to 124,000 troy ounces in 1978 and 145,000 troy ounces in 1979. In 1979, Indium Corp.'s new plant in Marseilles, France, commenced production. A major change in world trade patterns occurred during 1978-79 with the absence of exporting activity by the U.S.S.R. and Mainland China; both had been major exporters of indium in prior years, but became net importers in 1978-79.

RADIUM[14]

During 1978 and 1979, radium was used mostly in the therapeutic treatment of cancer. Replacement of radium by radioisotopes of other elements in the treatment of cancer continued.

Domestic Production.—No radium production was reported in the United States during 1978 and 1979. Domestic demand was met by withdrawal from stocks. Radium Chemical Co., Inc., New York, was the main domestic supplier.

Consumption and Uses.—Radium was used mostly in the therapeutic treatment of cancer, but was being replaced by cesium for this purpose. Radium was also used in the manufacture of thickness or density gauges for use in paper mills, steel mills, and in the manufacture of plastics. Some of these gauges measure the density of coal slurries. As much as one-third of these types of gauges used radium. Radium was not as effective as some other radionuclides in these applications but had an advantage in that it did not have to be licensed by the Nuclear Regulatory Commission. Radium was also used as calibration sources and laboratory standards. About 850 grams of radium was used in the United States in 1978 and 1979. The Environmental Protection Agency (EPA) owned and operated a depository for radium in Montgomery, Ala. This depository, in 1978, received 72 shipments of radium totaling approximately 12,448 milligrams. In 1979, 19 shipments of radium totaling approximately 4,077 milligrams were received. The radium disposal program was inactive for about 16 weeks in 1979, as the EPA was in the process of replacing all of its shipping containers. The quantity of radium stored at the depository at the end of 1979 was approximately 116 grams.

Prices.—The price of radium, per milligram, unencapsulated, as quoted by Radium Chemical Co., in 1978 and 1979 was $35.00.

Foreign Trade.—Data on trade in radium in 1978 and 1979 were included with data on other radioactive materials.

World Review.—Information on radium in world markets was not readily available. The Belgium company, Union Miniere S.A., believed to be the largest radium producer and supplier, stopped producing radium in 1978. Amersham and Buchler, Braunschweig, Federal Republic of Germany, was reported to be the leading supplier of radium. Small quantities of radium were also apparently produced in Canada, the United Kingdom, and in some centrally controlled economy countries. The industrial nations consumed most of the radium in use patterns similar to those in the United States.

Technology.—During uranium extraction, nearly all the radium remains in the mill tailings, causing storage and possible environmental problems.

The Center for Human Radiobiology, Argonne National Laboratory, issued a report on the status of the study of radium in humans.[15]

EPA concluded a study of the effects on health of exposure to radiation from radium-226, which reportedly occurred in structures built on phosphate lands in Florida. The report evaluated radiation levels in existing structures and concluded that over a normal lifetime, persons residing in homes on phosphate lands in the study area experience an average lung cancer risk 35% greater than normal, and that those residing in homes exhibiting the highest radiation levels measured experience risk of lung cancer two to four times the U.S. average.[16]

The U.S. Geological Survey reported that the discharge of hot springs in Jefferson County, Mont., contained high concentrations of radon, and the gross alpha activity and the concentration of radium-226 exceeded maximum levels recommended by EPA for drinking water.[17]

SCANDIUM[18]

Minor quantities of scandium were consumed in 1978 and 1979. Imports and industry stocks were sufficient to meet demand. One domestic producer provided the majority of scandium metal and compounds consumed.

Legislation and Government Programs.—New tariff rates for the mineral and metal category in which scandium was reported resulted from the 1979 Tokyo round of tariff negotiations, giving most nations Most Favored Nation status. The tariffs for these nations will decline annually, in stages, beginning January 1, 1980, and ending January 1, 1987.

Domestic Production.—In 1978 and 1979 there was no domestic mine production of scandium minerals. Research Chemicals, a division of Nucor Corp., Phoenix, Ariz., remained the principal producer of scandium oxide, metal, and compounds. Trading companies supplied most of the remaining demand with imports.

Consumption and Uses.—Only a small quantity of scandium in all forms was consumed, primarily for research and development. Scandium was also used to manufacture special scandium iodide high-intensity lamps and as a tracer (radioisotope scandium-46) in petroleum production. A scant quantity of scandium was consumed by the chemical and electronic industries.

Prices.—Yearend prices of scandium metal and compounds were quoted by Research Chemicals as follows:

Item	1978		1979	
	Per gram, 1 to 99 grams	Per gram, 100 to 453 grams	Per gram, 1 to 99 grams	Per gram, 100 to 453 grams
Ingots	$11.00	$ 9.00	$11.00	$ 9.00
Powder	13.50	11.00	13.50	11.00
Chips	12.50	10.00	12.50	10.00
Distilled	20.00	15.00	20.00	15.00
Oxide:				
99.99%	5.00	3.50	5.00	4.00
99.9%	3.50	2.65	4.00	3.20
Salts[1]	2.80	2.30	2.80	2.30

[1] Salts include acetates, carbonates, chlorides, nitrates, and oxalates in most stable, hydrous form produced from oxides of 99.9% minimum purity.

Foreign Trade.—There were no official U.S. foreign trade statistics for scandium. Data on scandium were included in data for other minerals and metals, n.e.c. (not elsewhere classified); however, trade was believed to be minor. Based on available information, Australia and the centrally controlled economy countries were the principal suppliers of scandium-bearing raw materials.

World Review.—Information on scandium-related activities in foreign countries was not readily available.

Technology.—Small quantities of scandium were detected using quantitative microprobe analysis of the nonmagnetic separate from rutile float concentration and magnetic separate from monazite- rutile float concentrate derived from the ore of the Climax molybdenum mine, Lake County, Colo.[19]

The heat capacity of three different electrotransport refined scandium samples were measured for 1 to 20°K and the resultant thermodynamic parameters given. The influence of magnesium, iron, and zirconium impurities on the heat capacity of scandium were also observed.[20]

The electrical resistivity of scandium-hydrogen alloys containing a maximum of 25 atomic percent hydrogen was observed between 4.2 and 300°K. At heating or cooling rates of 1°K per minute, no hysteresis was observed in the electrical resistivity.[21]

SELENIUM[22]

Higher copper prices in 1979 encouraged more production of copper and its associated byproduct, selenium. Prices of selenium weakened in 1979 as consumption declined to its lowest level since 1967.

Legislation and Government Programs.—Effective January 1979, the Food and Drug Administration extended the use of selenium as a feed additive for sheep and allowed its use for beef and dairy cattle.

Table 9.—Salient selenium statistics

(Pounds of contained selenium)

	1975	1976	1977	1978	1979
United States:					
Production, primary	357,722	400,609	499,475	508,636	587,118
Shipments to consumers	284,479	369,588	353,098	324,378	467,338
Imports for consumption	889,320	811,257	585,673	799,853	683,903
Exports, metal, waste and scrap	117,596	193,484	67,610	227,449	333,282
Shipments from Government stocks	6,169	2,470	---	---	---
Apparent consumption	1,062,372	989,831	871,161	896,782	817,959
Stocks, yearend, producer	152,373	176,742	323,119	507,377	627,157
Producer's price, average per pound, commercial and high-purity grades	$18-$22	$18-$22	$17.12-$20.86	$15-$18	$13.65-$15.31
World: Refinery production	2,608,356	[r]2,477,784	3,020,950	3,192,758	3,443,931

[r] Revised.

Domestic Production.—During 1978 and 1979, primary selenium was recovered at three copper refineries: AMAX Copper, Inc., Carteret, N.J.; ASARCO Incorporated, Amarillo, Tex.; and Kennecott Corp., Magna, Utah. AMAX, Inc., toll-refined selenium for the Phelps Dodge Corp.

Anode slimes recovered from the electrolytic tanks and residues of pollution abatement plants at domestic and foreign nonferrous smelters and refineries also were shipped to these plants for recovery of gold, silver, selenium, and tellurium. High-purity selenium metal and various selenium compounds were produced by the three copper refineries and other processors from commercial-grade metal.

Most of the U.S. selenium scrap supply is sent to Canada for reprocessing and returned to U.S. markets for consumption. Selenium scrap is recovered from xerographic, rectifier, and chemical processes. The selenium coated on xerographic drums is nearly 100% recoverable as either high-purity or commercial-grade selenium.

Consumption and Uses.—The following are estimates of selenium consumption by end-use categories in 1978 and 1979: Electronic and photocopier components, 35%; glass manufacturing, 30%; chemicals and pigments, 25%; and other, 10%. Consumption of selenium increased slightly in 1978 and then dropped in 1979. Increased recycling of xerography drums reduced demand for virgin selenium in the photocopier industry, and disappointing auto sales adversely affected selenium pigment and free machining steel consumption.

Stocks.—U.S. producer stocks continued to rise, and represented about 9 months of supply at the 1979 rate of apparent consumption.

Prices.—Selenium is usually sold as a commercial grade (99.5% minimum) and as a high-purity grade (99.9% minimum) powder available in varying mesh sizes. Pellets and sticks are also sold.

Domestic producer prices for commercial-grade and high-purity selenium have declined every year since 1976. Prices were stable in 1978 but dropped twice in 1979, once in April and again in October. U.S. and European dealer prices ranged from a high of $13.75 - $14.50 per pound in June 1978 to a low of $9.00 -$9.75 per pound in November 1979. Prices at yearend 1979 were $9.15 - $9.75 per pound.

Low prices were a result of continued high rates of selenium production both in the U.S. and Canada.

Foreign Trade.—Selenium exports more than tripled in 1978 and increased significantly in 1979. In 1978 and 1979, a new practice of including in trade statistics selenium waste and scrap as well as a selenium metal was begun. Much of the selenium exported to Japan in those 2 years was waste, scrap, and crude forms.

Table 10.—U.S. exports of selenium metal, waste, and scrap, by country

Country	1978		1979	
	Quantity (pounds)	Value	Quantity (pounds)	Value
Argentina	--	--	500	$6,250
Australia	4,651	$20,930	500	6,750
Belgium-Luxembourg	--	--	814	6,260
Brazil	4,216	53,778	--	--
Canada	5,646	53,970	1,419	12,769
Colombia	3,307	34,233	--	--
Dominican Republic	--	--	607	12,810
France	132	1,588	2,404	51,912
Germany, Federal Republic of	11,245	167,130	15,188	138,556
India	1,748	23,925	107	2,605
Italy	--	--	1,166	14,300
Japan	78,088	899,617	51,948	296,622
Mexico	1,812	15,798	--	--
Netherlands	87,200	388,410	100,005	1,091,672
Portugal	324	2,653	--	--
South Africa, Republic of	880	12,038	--	--
Spain	4,400	51,480	2,400	26,400
Sweden	--	--	110	3,132
Switzerland	86	2,665	--	--
United Kingdom	73,714	250,773	154,007	2,174,176
Venezuela	--	--	2,112	25,978
Total	227,449	1,578,988	333,282	3,870,192

Table 11.—U.S. imports for consumption of selenium, by country

(Pounds of contained selenium)

Country	1978 Quantity	1978 Value	1979 Quantity	1979 Value
Unwrought and waste and scrap:				
Australia	2,205	$24,912	--	--
Belgium-Luxembourg	41,711	747,921	52,970	$842,555
Canada	228,948	4,787,678	322,951	6,331,251
Chile	30,690	388,776	8,817	101,230
Finland	1,102	13,834	661	6,895
France	20	300	598	7,475
Germany, Federal Republic of	15,860	236,768	17,073	203,343
Japan	230,340	2,806,652	120,380	1,691,975
Mexico	24,252	244,535	11,022	120,733
Netherlands	4,400	41,864	--	--
Peru	7,800	112,648	--	--
Sweden	5,776	121,459	19,004	403,207
United Kingdom	22,991	232,292	25,067	283,559
Yugoslavia	105,238	1,140,838	66,052	673,387
Zambia	11,000	80,341	17,033	222,429
Total	732,333	10,930,818	661,628	10,888,039
Selenium dioxide:				
Germany, Federal Republic of	34,349	384,144	15,410	175,583
Sweden	6,173	29,289	--	--
United Kingdom	2	429	2	429
Total	40,524	453,862	15,412	176,012
Selenium Salts:				
Ireland	--	--	53	753
Japan	--	--	463	14,942
United Kingdom	2,166	3,413	3,763	8,945
Total	2,166	3,413	4,279	24,640
Other selenium compounds:				
Germany, Federal Republic of	20,061	267,833	--	--
Japan	1,550	35,503	529	14,942
Sweden	2,227	38,882	28	508
United Kingdom	992	14,628	2,027	19,130
Total	24,830	356,846	2,584	34,580
Total, all forms	799,853	11,744,939	683,903	11,123,271

Significant revisions of tariff rates on many mineral commodities, including selenium, resulted from an agreement reached in 1979 in Tokyo between the developed nations of the world. The tariff rate for other selenium compounds (TSUS 420.54) was scheduled to be reduced in gradual stages beginning January 1, 1980, and ending January 1, 1987. The following tabulation indicates scheduled changes in the U.S. tariff rates for selenium. The tariff rate for Non-MFN remained free for selenium metal and selenium dioxide and 25% ad valorem for other selenium compounds.

Item	Number	Most Favored Nation (MFN) 1/1/79	Most Favored Nation (MFN) 1/1/80	Most Favored Nation (MFN) 1/1/87
Selenium metal	632.40	Free	Free	Free.
Selenium dioxide and salts	420.50, 420.52	Free	Free	Free.
Other selenium compounds	420.54	5% ad valorem	4.8% ad valorem	3.7% ad valorem.

World Review.—World refinery production of selenium increased in both 1978 and 1979, with both Japan and Canada contributing about 1 million pounds each. The U.S.S.R. is known to be a major producer, but data are insufficient to estimate annual production.

United Kingdom.—Johnson Matthey Chemicals Ltd. began producing commercial-grade selenium at its Brimsdown refinery near London. The company currently extracts precious metals from copper tankhouse slimes. Estimated capacity from the plant could be as much as 220,000 to 260,000 pounds per year.

Zambia.—A refinery owned by Roan Consolidated Mines Ltd. (RCM) began producing selenium in November 1977.

Table 12.—Selenium: World refinery production, by country[1]

(Pounds)

Country[2]	1976	1977	1978[p]	1979[e]
Belgium[e]	130,000	130,000	130,000	130,000
Canada[3]	499,168	905,111	865,924	[4]1,128,113
Chile	33,160	18,291	[e]18,000	18,000
Finland	21,894	25,693	37,104	39,700
Japan	[r]1,014,125	1,005,306	[e]1,100,000	1,000,000
Mexico	[r]127,868	110,231	176,369	181,000
Peru	19,299	35,097	28,499	30,000
Sweden	[r]132,277	145,505	147,710	150,000
United States	400,609	499,475	508,636	[4]587,118
Yugoslavia	99,384	111,024	112,435	110,000
Zambia	--	35,217	68,081	70,000
Total	[r]2,477,784	3,020,950	3,192,758	3,443,931

[e]Estimate. [p]Preliminary. [r]Revised.

[1] Insofar as possible, data relate to refinery output only; thus, countries that produce selenium contained in copper ores, copper concentrates, blister copper, and/or refinery residues, but do not recover refined selenium from these materials indigenously are excluded to avoid double counting.

[2] In addition to the countries listed, Australia, the Federal Republic of Germany, and the U.S.S.R. produce refined selenium, but output is not reported, and available information is inadequate for formulation of reliable estimates of output levels. Australia is known to produce selenium in intermediate metallurgical products (Peko Wallsend Ltd. at June and Warrego mines, Tennant Creek) and has facilities to produce elemental selenium (Port Kembla refinery of the Electrolytic Refining and Smelting Co. of Australia Pty Ltd.); output by Peko Wallsend is not reported in order to avoid double counting, and output, if any, by the Port Kembla refinery is unreported.

[3] Refinery output from all sources, including imported materials and secondary sources.

[4] Reported figure.

Technology.—Selenium sometimes occurs in zinc ores and is combined with the zinc sulfide concentrates from such ores. During roasting operations to remove sulfur from the concentrates, water is used to clean the gases generated. The resulting waste water is acidic and sometimes contains up to 15 parts per million of selenium. Water quality standards have been set for acidity, and standards for selenium content of waste water are under consideration by EPA. In current practice, acidity of the waste water is neutralized with lime, which also precipitates some selenium. The Bureau of Mines investigated the removal of selenium from zinc smelter acidic gas scrubber effluents by using zinc dust to precipitate soluble selenium prior to the lime neutralization.[23] The method resulted in an effluent containing less than 0.1 part per million of selenium. The treatment method was tested successfully both in the laboratory and at a smelter site. During the research, a rapid visual method also was developed for determining the concentration of selenium in waste water.

The 1976 proceedings of the symposium on Selenium-Tellurium in the Environment became available from the Selenium-Tellurium Development Association, Inc.[24] Subjects covered included selenium in foods, selenium in the atmosphere, the biological function of selenium, and the effect of selenium intake in humans and rats.

TELLURIUM[25]

Domestic Production.—Tellurium and tellurium dioxide was recovered domestically as a byproduct of electrolytic copper refining by AMAX Copper, Inc., at Carteret, N.J., and ASARCO Incorporated at Amarillo, Tex. AMAX, Inc. toll-refined tellurium for the Phelps Dodge Corp. High-purity tellurium, tellurium master alloys, and tellurium compounds were produced by primary and intermediate processors from commercial-grade metal and tellurium dioxide. Domestic production and producer stocks increased in 1978, but in 1979, they decreased from that of the preceding year. Shipments of tellurium increased in both 1978 and 1979. Figures have been withheld to avoid disclosing company proprietary data. According to the American Bureau of Metal Statistics, shipments of refined tellurium to customers in the United States increased from 254,000 pounds in 1977, to 304,000 pounds in 1978, and to 430,000 pounds in 1979. Data for 1977 and 1978 included production from three domestic and three foreign firms; 1979 data included production from an additional foreign firm.

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Table 13.—Salient tellurium statistics

(Pounds of contained tellurium)

	1975	1976	1977	1978	1979
United States:					
Refinery production	130,844	W	W	W	W
Shipments to consumers	163,089	W	W	W	W
Imports for consumption	97,350	203,534	171,291	173,989	167,760
Apparent consumption	260,439	390,503	393,479	402,232	494,010
Stocks, yearend, producer	55,196	W	W	W	W
Producers' price: Average per pound, commercial grade	$9.28	$10.33	$17.15	$20	$20
World: Refinery production[1]	[r]314,950	([2])	([2])	([2])	([2])

[r] Revised. W Withheld to avoid disclosing company proprietary data.

[1] Excludes U.S. production from 1976 to 1979.

[2] See World Production table.

Consumption and Uses.—Consumption of tellurium has increased every year since 1976. Tellurium consumption by end use in 1979 was estimated as follows: Iron and steel production, 57%; chemical uses, 25%; nonferrous metal production, 14%; and other uses including rubber manufacturing, 4%. The estimated chemical usage of tellurium has increased sharply in the past few years due to greater catalytic applications of tellurium dioxide in processing petrochemicals. A large domestic consumer of catalyst-grade tellurium shut down its plant late in 1979.

Prices.—The producer price of tellurium metal quoted by Metals Week has remained unchanged at $20 per pound, since September 1977. Tellurium metal is usually marketed in the form of minus 200-mesh powder or as slabs, tablets or sticks. Normal commercial grades contain a minimum 99% or 99.5% tellurium. Tellurium dioxide is sold in the form of minus 40 to minus 200-mesh powder containing a minimum 75% tellurium.

Table 14.—U.S. imports for consumption of tellurium, by country

Country	1978		1979	
	Quantity (pounds)	Value	Quantity (pounds)	Value
Unwrought and waste and scrap:				
Belgium-Luxembourg	13,965	$224,374	551	$16,010
Canada	30,520	708,155	17,930	582,390
Fiji	30,622	599,052	2,205	39,989
Germany, Federal Republic of	59	3,627	58	12,365
Italy	--	--	4	432
Japan	10,497	229,509	2,821	49,192
Peru	20,401	481,566	3,641	70,650
United Kingdom	5,078	131,963	9,513	188,780
Total	111,142	2,378,246	36,723	959,808
Compounds:				
Canada	36,353	597,868	88,157	1,492,788
Fiji	22,400	394,220	16,080	249,154
Germany, Federal Republic of	3	473	12	1,912
Hong Kong	--	--	19,511	341,736
Japan	4,065	64,661	7,266	142,963
United Kingdom	15	2,181	11	338
Total	62,836	1,059,403	131,037	2,228,891
Salts: Germany, Federal Republic of	11	1,058	--	--
Grand total	173,989	3,438,707	167,760	3,188,699

Foreign Trade.—There are no data on tellurium exports.

The average value of imported tellurium metal and scrap increased to $21.40 per pound in 1978, and to $26.14 per pound in 1979. The average value of imported tellurium compounds increased to $16.86 per pound in 1978 and to $17.01 per pound in 1979.

In recent years, the quantity of imported tellurium compounds has been increasing at a faster rate than the quantity of imported tellurium metal, waste, and scrap. The year 1979 marked the first time imports of compounds exceeded imports of metal, waste, and scrap.

Significant revisions of tariff rates on many mineral commodities, including tellurium, resulted from an agreement reached in 1979 in Tokyo between the developed nations of the world. The tariff rates for tellurium metal (TSUS 632.48) and tellurium compounds (TSUS 421.90) were scheduled to be reduced in gradual stages beginning January 1, 1980, and ending January 1, 1987. The following tabulation indicates scheduled changes in the U.S. tariff rates for tellurium.

Item	Number	Most Favored Nation (MFN)		
		1/1/79	1/1/80	1/1/87
Metal	632.48	4% ad valorem	3.5% ad valorem	Free.
Compounds	421.90	5% ad valorem	4.8% ad valorem	3.7% ad valorem.
Salts	427.12	5% ad valorem	5% ad valorem	5% ad valorem.

There was no change in the 25% ad valorem rate charged for all categories of tellurium imported from Non-Most Favored Nations.

World Review.—World production of tellurium, excluding the United States, remained at about the same level in 1978 as in 1977, but increased substantially in 1979 due to initial tellurium production in Hong Kong.

Fiji.—Tellurium production originated as a byproduct of indigenous gold production and from imported copper slimes. The copper slimes were obtained from the United States and accounted for a much larger source of tellurium production than did gold ore. Most of the refined tellurium produced was sold in the United States.

Hong Kong.—A new producer, Metal Refiners (Asia) Ltd., began production of catalyst-grade tellurium dioxide and tellurium metal beginning March 1, 1979. Metal Refiners' expected capacity is about 130,000 pounds per year, making it one of the largest producers in the world.

Japan.—Dramatic growth in producing and exporting both tellurium and selenium in recent years has been a result of increasing use of purchased process soda-ash-slag-bearing residues of selenium and tellurium from all parts of the world. The slag is left after silver and gold have been removed from copper slimes.

Table 15.—Tellurium: World refinery production, by country[1]

(Pounds)

Country[2]	1976	1977	1978^{p}	1979^{e}
Canada[3]	117,156	81,617	99,867	[4]104,065
Fiji	2,446	^{e}27,000	^{e}50,000	50,000
Hong Kong	--	--	NA	100,000
Japan	73,634	143,521	^{e}162,000	170,000
Peru	^{r}27,130	40,499	33,911	35,000
United States	W	W	W	W

^{e}Estimate. ^{p}Preliminary. ^{r}Revised. NA Not available. W Withheld to avoid disclosing company proprietary data.

[1] Insofar as possible, data relate to refinery output only; thus, countries that produce tellurium contained in copper ores, copper concentrates, blister copper, and/or refinery residues, but do not recover refined tellurium, are excluded to avoid double counting. Table is not totaled because of the exclusion of data from major world producers, notably the United States and the U.S.S.R.

[2] In addition to the countries listed, Australia, Belgium, the Federal Republic of Germany, and the U.S.S.R. are known to produce refined tellurium, but output is not reported, and available information is inadequate for formulation of reliable estimates of output levels. Moreover, other major copper refining nations such as Chile, Zaire, and Zambia may produce refined tellurium, but output in these nations is conjectural.

[3] Refinery output from all sources, including imports and secondary sources.

[4] Reported figure.

Technology.—A research laboratory of AMAX Copper Inc. in conjunction with the Selenium Tellurium Development Association, Inc., developed a new process for adding tellurium to powder metallurgy steels in order to improve steel machinability.[26] When tellurium alone was added to powder metallurgy steel, excessive loss of tellurium during sintering or severe cracking during hot extrusion of the steel occurred. But when 0.1% tellurium together with 0.5% copper was added, those problems were overcome.

In a Battelle Memorial Institute study under contract with the U.S. Department of Energy, tellurium was included as one of eight elements identified as posing severe material constraints if selected for large-scale use in a cadmium sulfide-cadmium telluride solar electric cell.[27]

THALLIUM[28]

Domestic Production.—The principal source of commercial thallium is the trace amount found in sulfide ores of other metals. The supply is derived from processing selected smelter flue dusts and residues of the particular base metal ores. The Globe plant of ASARCO Incorporated at Denver, Colo., was the only domestic producer of thallium and thallium compounds.

Production of chemicals was much lower in 1978 and 1979 compared with that of 1977, but shipments were about the same.

Uses.—The current uses of thallium include electronic components, low-melting alloys, low-temperature thermometers, additives for changing the refractive index of glass, photosensitive devices, and as an additive to mercury lamps. Thallium-activated sodium iodide crystals are used in gamma radiation detection equipment.

Prices.—The price of thallium in 25 pound lots was $7.50 per pound throughout 1978 and 1979.

Foreign Trade.—As a result of the Tokyo Round of multi-lateral trade negotiations completed in 1979, the rates of duty for thallium were changed as follows:

Item	Number	MFN		Non-MFN
		1/1/80	1/1/87	1/1/80
Unwrought metal, and waste and scrap	632.50	4.4% ad valorem	Free	25% ad valorem.
Compounds	422.00	4.8% ad valorem	3.7% ad valorem	25% ad valorem.

Table 16.—U.S. imports for consumption of thallium in 1978 and 1979, by country

Country of origin	1978				1979			
	Compounds (gross weight)		Unwrought, and waste and scrap		Compounds (gross weight)		Unwrought, and waste and scrap	
	Pounds	Value	Pounds	Value	Pounds	Value	Pounds	Value
Belgium-Luxembourg	50	$2,015	--	--	37	$1,690	--	--
Canada	--	--	4	$763	--	--	--	--
France	--	--	--	--	7	325	--	--
Germany, Federal Republic of	483	18,294	22	475	889	27,922	--	--
Taiwan	--	--	--	--	1	300	--	--
United Kingdom	28	1,212	--	--	13	537	2	$357
Total	561	21,521	26	1,238	947	30,774	2	357

World Review.—World mine production data for thallium were not available. U.S. reserves in zinc ores were estimated at 200,000 pounds at the end of 1979.

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[3] ———. Office of Pesticide Programs. V. 43, No. 202, Oct. 18, 1978, pp. 48267-48298.

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Minor Nonmetals

By Staff, Section of Nonmetallic Minerals

CONTENTS

	Page
Asphalt	1051
Greensand	1051
Iodine	1051
Meerschaum	1056
Quartz crystal	1056
Staurolite	1058
Strontium	1059
Wollastonite	1062
Zeolites	1062

ASPHALT (NATIVE)[1]

Native asphalt was produced in 1978-79 by six companies in four States. Leading States were Texas and Utah. Output increased 37% in 1978 to 1.7 million tons and decreased 5% in 1979 to 1.6 million tons while value increased 39% in 1978 to $19.3 million and 33% in 1979 to $25.6 million.

Bituminous limestone was produced by Whites Uvalde Mines and by Uvalde Rock Asphalt Co. in Uvalde County, Tex.; by Southern Stone Co. in Colbert, Ala.; and by Barton County Rock Asphalt Co. in Barton County, Mo. The product was used mainly in street and road repair.

Gilsonite was produced by American Gilsonite Co. in Uinta County, Utah, and by Ziegler Chemical and Mineral Corp. in Weber County, Utah. This material was used for purposes other than road repair.

GREENSAND[2]

Greensand (glauconite) was produced in 1978-79 only by the Inversand Co., a subsidiary of Hungerford and Terry Inc., near Clayton, N.J. Production and sales information is withheld to avoid disclosing company proprietary data.

Raw greensand produced by the company was sold for agricultural use as a soil conditioner. It contains both potassium and phosphorus. Processed greensand was sold as a filter media for the removal of manganese, iron, sulfide, and other elements from water.

IODINE[3]

U.S. demand for crude iodine in 1978 and 1979 was satisfied in part by increased domestic production and withdrawals from the surplus world supply accumulated in prior years. By 1979, however, the iodine market was becoming unbalanced with demand exceeding supply. During the 2-year period, the quoted price of crude product was raised five times, and reached $4.54 per pound by yearend 1979. Faced with rising prices and the possibility of shortages, U.S. chemical companies stockpiled iodine supplies in 1978 for consumption in 1979 and future years.

The two U.S. producers of crude iodine increased output to record high levels, but U.S. capacity was less than one-fourth of domestic requirements. Japan, which was by far the largest producer of iodine, and Chile were the major sources of supply to U.S. and world markets; however, difficulties with subsidence, drought, inflation of costs, and the weakness of the U.S. dollar relative to the yen had a detrimental effect on Japanese iodine production. Japanese plants were operating substantially below theoretical capacity. Although Chilean output increased in 1978 and 1979, Chilean capacity was insufficient to maintain the balance in supply and demand.

Legislation and Government Programs.—On December 31, 1978 and 1979, the U.S. Government strategic stockpile showed an inventory of 8,010,000 pounds of crude iodine. The stockpile inventory goal was established at 3,333,000 pounds in 1976. None of the excess of 4,677,000 pounds has been authorized for disposal.

The depletion allowance for iodine remained at 14% of gross income, and may not exceed 50% of net income without the depletion deduction.

Domestic Production.—In 1978, its second year of production, Woodward Iodine Operations of Woodward, Okla., increased output and sales 75%. In 1979, output and sales increased 7%. Woodward Iodine is a joint venture between Amoco Production Co. (49%) and PPG Industries, Inc. (51%). The operation is unique in comparison with iodine operations in Michigan, Chile, and Japan because iodine is the only commercial product. Amoco operates wells that pump brines and natural gas to the PPG plant where iodine of greater than 99.9% purity is recovered by the conventional vapor stripping process with incorporated proprietary refinements. To date, iodine output has not approached the design capacity of 2 million pounds per year. In 1979, strong demand and some operational difficulties that limited output forced PPG, which also markets iodine, to allocate supplies to customers. PPG introduced a United States Pharmacopeia (U.S.P.) grade product to the market in 1979, but sales were minimal because most of its iodine production was needed to supply crude iodine customers.

The Dow Chemical Co. recovered iodine as a coproduct of bromine, calcium and magnesium compounds, and potash from subterranean brines at Midland, Mich. Dow's iodine production increased in 1978 and also in 1979. Reported capacity for iodine extraction was 500,000 pounds.[4] Most, if not all, of the Dow product was retained for captive use.

Consumption and Uses.—According to the Bureau of Mines canvass for 1978, crude iodine was consumed by 30 plants in 14 States. Seventeen of the plants, which were located in the leading consumer States of Missouri, Georgia, Pennsylvania, New Jersey, and California (in decreasing magnitude of consumption), accounted for 80% of the total reported iodine consumption.

The 1979 Bureau of Mines canvass indicated a decline in crude iodine consumed in 31 plants in 14 States. Eighteen of these plants, which were located in the leading consumer States of Missouri, Pennsylvania, New Jersey, California, and Georgia (in decreasing magnitude of consumption), accounted for 86% of the total reported iodine consumption. Comparison of the 1979 canvass with 1978 figures showed a decrease in consumption of crude iodine for making both organic and inorganic iodine compounds and resublimed iodine.

While the canvass information indicates a general consumption pattern, establishing an accurate pattern of demand by end use is difficult because iodine is frequently converted into intermediate compounds and marketed as such before reaching its ultimate end use. Moreover, iodine and iodides used in catalytic and other dissipative processes are not well covered. This situation has been revealed consistently in recent years by import figures that exceeded reported consumption figures; in 1978 and 1979, crude iodine imports exceeded reported consumption by 437,000 pounds and 301,000 pounds, respectively. Combining imports with domestic production, estimated exports, and consumer inventory accumulations, apparent consumption in 1978 was about 8.1 million pounds. In 1979, despite fewer iodine imports, apparent consumption rose to 8.7 million pounds. Substantial withdrawals from consumer company inventories and greater domestic production were responsible for the increase in apparent consumption.

The major downstream uses for iodine in 1978 were estimated as follows: Catalysts (for synthetic rubber, stabilized rosin, tall oil, and other uses), estimated at 21%; animal feed supplements (mainly for cattle), 21%; inks and colorants, 16%; stabilizers (as in nylon precursors), 14%; pharmaceuticals, 12%; sanitary and industrial disinfectants, 7%; photographic film, 4%; and other uses, 5%. Other uses includes the making of high-purity metals, motor fuels, iodized salt, smog inhibitors, and lubricants. Iodine also has application in cloud seeding and radio-opaque diagnosis in medicine. The end uses for iodine that appeared to have experi-

Table 1.—Crude iodine consumed in the United States

Products	1977			1978			1979		
	Number of plants	Consumption		Number of plants	Consumption		Number of plants	Consumption	
		Thousand pounds	Percent of total		Thousand pounds	Percent of total		Thousand pounds	Percent of total
Reported consumption:									
Resublimed iodine	6	506	9	9	639	10	12	635	11
Potassium iodide	7	1,237	21	11	1,279	20	9	1,155	19
Sodium iodide	4	77	1	4	117	2	4	113	2
Other inorganic compounds	14	1,705	29	11	2,052	32	18	1,791	30
Organic compounds	20	2,376	40	14	2,315	36	15	2,235	38
Total	[1]31	[2]5,900	100	[1]30	[2]6,400	100	[1]31	[2]5,900	100
Apparent consumption	XX	8,600	XX	XX	8,100	XX	XX	8,700	XX

XX Not applicable.

[1] Nonadditive total because some plants produce more than one product.

[2] Data may not add to total shown because of independent rounding.

enced significant growth in 1978 were animal feed supplements and inks and colorants.

The major downstream uses for iodine in 1979 were estimated as follows: Catalysts (25%), animal feed additives (21%), pharmaceuticals (15%), sanitary preparations (11%), stabilizers (10%), inks and colorants (7%), photography (4%), and other (7%). Use of iodine for sanitation purposes increased rapidly. Although most categories of consumption continued to grow in 1979, a dramatic decrease in demand for crude iodine occurred in the inks and colorants category as rising iodine prices increased the attractiveness of substitute chemicals.

Prices.—The quoted price at the beginning of 1978 of $2.31 per pound of crude iodine was raised twice during the year, first to $2.59, then to $3.10. Additional increases to $3.63, $4.03, and $4.54 followed in 1979. In one instance in 1979, the major marketer of U.S.-produced iodine, PPG Industries, initiated the price increase. This was a departure from past price changes, which have traditionally been announced first by the Japanese Iodine Exporters Association.

Rising demand and production costs, and the deteriorating relationship of the dollar to the yen were significant factors affecting price in 1978-79, although the dollar-yen situation improved in 1979. Discounted sales prices for quantity purchases increased also. As the leading vendor of crude iodine in world markets, Japan exemplified this upward trend in discount prices. Exports of Japanese iodine had an average value of $2.20 per pound in 1978 and $3.04 per pound in 1979. Owing to the availability of improved information, the 1978 figure was revised from a previously reported figure.

Table 2.—Quoted prices of elemental iodine and selected iodine compounds[1]

	Value per pound, Dec. 31	
	1978	1979
Iodine, crude, drums	[2]$3.10	$4.54
Resublimed iodine, U.S.P., granular, 100-pound drums, works	5.86	7.24
Calcium iodate, drums, delivered	3.32	3.32
Calcium iodide, 35-pound drums, works	5.98	5.98
Potassium iodide, U.S.P., granular, crystals, drums, 1,000-pound lots, delivered	4.18	5.32
Sodium iodide, U.S.P., crystals, 300- to 500-pound lots, drums, freight equalized	6.16	7.41
Iodoform, N.F., 300-pound drums, f.o.b. works	$7.75-14.30	$7.75-14.30

[1] Conditions of final preparation, transportation, quantities, and qualities not stated are subject to negotiation and/or somewhat different price quotations.

[2] Chemical Marketing Reporter, V. 214, No. 21, Nov. 20, 1978, p. 24.

Source: Chemical Marketing Reporter, v. 215, No. 1, Jan. 1, 1979, pp. 46-55, and V. 216, No. 27, Dec. 31, 1979, pp. 26-35.

Foreign Trade.—The quantity of U.S. imports of crude iodine in 1979 was less than imports in 1978, while the total value was higher. The increase in the average U.S. Customs declared value from $2.14 per pound in 1978 to $2.98 per pound in 1979 reflected the growth in iodine prices. Imports of Japanese iodine declined from 1978 to 1979, whereas imports of Chilean iodine increased. In addition, small quantities of iodine were imported in 1979 from nontraditional sources.

Imports of resublimed iodine, mostly from Japan, amounted to 83,613 pounds in 1978 and 21,773 pounds in 1979.

Tariff rates were 8 cents per pound on resublimed iodine and 12 cents per pound on potassium iodide. Crude iodine enters the United States duty free.

Table 3.—U.S. imports for consumption of crude iodine, by country

(Thousand pounds and thousand dollars)

Country	1977		1978		1979	
	Quantity	Value	Quantity	Value	Quantity	Value
Canada	7	4	--	--	--	--
Chile	1,543	2,860	1,102	2,425	1,342	4,314
Indonesia	--	--	--	--	13	40
Japan	5,390	[r]10,968	5,734	12,208	4,838	14,073
Mexico	--	--	--	--	1	2
United Kingdom	--	--	--	--	7	25
Total[1]	6,940	13,831	6,837	14,633	6,201	18,454

[r] Revised.

[1] Data may not add to totals shown because of independent rounding.

Source: U.S. Department of Commerce, Bureau of the Census.

World Review.—Iodine producing nations include Japan, Chile, the United States, the U.S.S.R., China, and Indonesia.

Chile.—Although the 1978 devaluation of the Chilean peso with respect to the U.S. dollar placed the Chilean iodine producer in a more secure position than that of Japanese producers, price increases initiated by Japanese marketers were followed by Chilean marketers.

Iodine is a byproduct of potassium and sodium nitrates extracted from Chile's caliche deposits. The Government-owned mining concern, Sociedad Quimica y Minera de Chile S.A. (SOQUIMICH), produced nitrates and iodine from three mines and plants: Pedro de Valdivia, Maria Elena, and Victoria. According to a SOQUIMICH spokesman, iodine production goals for 1979 were 2.6 million pounds at Pedro de Valdivia, 1.2 million pounds at Maria Elena, and 170 thousand pounds at Victoria.[5] Through programs designed by Saline Processors, a U.S. consulting firm, SOQUIMICH's plans to apply new technology in the production of iodine and nitrates are expected to be realized in part in the construction of an iodine plant at Maria Elena. Production was planned to begin in 1980.

Iceland.—One of the world's largest seaweed drying plants is now in operation in Iceland.[6] Rockweed, dulse, and kelp are harvested and processed for industrial and veterinary uses and human consumption. Areas of kelp containing high iodine concentrations have been located and production of an extract concentrate is underway.

Indonesia.—The iodine plant of the state-owned pharmaceutical concern, P.T. Kimia Farma, at Mojokerto, East Java, is the only crude iodine producer in Indonesia. Indonesia has traditionally exported about half of its iodine output and used the balance for the manufacture of pharmaceuticals.

Japan.—Production of crude iodine in Japan, the largest producer for the world market, was affected by environmental and economic difficulties. Output in 1978-79 remained well below the 1972 record of 16.5 million pounds. Strong world demand for Japanese iodine reduced inventories to below adequate reserve levels.

Ise Chemical Industries, Ltd., which produces about half of Japan's iodine, and the

Table 4.—Crude iodine: World production, by country

(Thousand pounds)

Country[1]	1976	1977	1978[p]	1979[e]
Chile	3,137	4,092	4,237	4,800
China, Mainland[e]	800	800	1,000	1,000
Indonesia	60	45	16	20
Japan	15,331	13,448	13,227	13,800
United States	W	W	W	W
U.S.S.R.[e]	5,000	5,000	5,000	5,000
World total[2]	24,000	23,000	23,000	25,000

[e] Estimated. [p] Preliminary. W Withheld to avoid disclosing company proprietary data.

[1] In addition to the countries listed, the Federal Republic of Germany is known to have produced elemental iodine in 1976 and may have continued to do so during 1977-1979, but output is not officially reported and available information is inadequate for formulations of reliable estimates of output levels.

[2] Data may not add to totals shown because of independent rounding.

other five producers operated near Tokyo on the Chiba Peninsula, where problems with subsidence have increased in recent years. Other problems for iodine producers in 1978, besides subsidence, were related to a drought and a lack of profitability in iodine production which was exacerbated by the weakness of the U.S. dollar.[7] Ise has developed additional resources at Miyazaki and Niigata, but continuing internal difficulties have delayed the company's expansion plans. The Miyazaki plant was reportedly not operating during part of 1978 and the Niigata plant cut back production by 50%. Although the dollar strengthened in relation to the yen in 1979, the situation had not improved sufficiently to encourage expansion of capacity. The Miyazaki operation remained at about one-fourth of its design capacity of 4.4 million pounds. The Niigata facility produced about 1.5 million pounds.

Japanese exports of crude iodine increased about 10% in 1978. Export values averaged $2.20 per pound (revised from a previously published figure). Exports to the United States amounted to 43% of the total of 13.3 million pounds of iodine shipped to 43 countries. The countries of the European Community represented another 36%, and other markets included India (7%), Canada (3%), and Poland (3%).[8]

In 1979, exports of Japanese iodine declined 8% to 12.2 million pounds. Export values increased to an average $3.04 per pound. Japan exported iodine to 30 countries, of which the United States accounted for 40%; the European Community, 41%; India, 4%; Canada, 4%; and Poland, 2%.[9]

Technology.—The U.S. Department of Energy published a report on methods to analyze oilfield brines for iodide and fluoride using selective ion electrodes.[10] Knowledge of the concentrations of these ions is needed in enhanced oil recovery research, environmental impact studies, and in locating recoverable chemicals. The laboratory technique was reported to be more accurate and faster than the previously used titration method and to cover a wider range of iodide concentrations. The detection limit was 10 milligrams per liter.

General Atomics Co. has reportedly solved most of the problems caused by side reactions in its experimental process to produce hydrogen from a thermochemical sulfur-iodine water splitting cycle.[11] The potential for hydrogen to emerge as the preferred way to deliver energy in the twenty-first century and the long-term requirement for a replacement for natural gas as a hydrogen source make water a logical future source of hydrogen energy. The Sagami Chemical Research Center in Japan, where similar research is being conducted, has developed a catalyst which it claims to be effective in the production of hydrogen from a hydrogen iodide recycle process.[12] The catalyst is composed of fine platinum particles scattered on a fluoride resin carrier. Early experiments have shown that at a temperature of 200° C the catalyst decomposed about 40% of the hydrogen iodide in 100 minutes. The catalyst, which does not react with hydrogen iodide, remained active for 200-300 hours.

Using computer simulation, researchers at the Marshall Space Flight Center, Huntsville, Ala., concluded that disposal in space is feasible for radioactive iodine waste from nuclear power reactors.[13] The space transportation system utilized would rely on the space shuttle, a liquid hydrogen-liquid oxygen orbit transfer vehicle, and a solid propellant final stage. The iodine was assumed to be in the form of either an iodide or an iodate, and calculations were based on the assumption that the final destination would be either solar orbit or solar system escape.

Study of the health effects on users of drinking water purified with iodine indicated no ill effects during a 15-year pilot project comprising a Florida prison community of 750 men and women.[14] Of primary interest were the possible effects of iodinated water on the thyroid function of adults and of infants born to female prisoners. The research was supported by Calabrian International, the Medical Research Service of the Veterans Administration, and the National Institutes of Health General Clinical Research Center grant RR-82.

West Design Chemical Group, a division of West Agro-Chemical, Inc., has announced a technological innovation in utilizing the microbiocidal properties of iodine.[15] Compared with current products, the invention reportedly accelerates iodine's rate of disinfecting while requiring less iodine and complexing agents. A spokesman for West-Agro, which holds patent technology on iodophors (iodine complexed by surfactants or polyvinyl pyrrolidine), believes that this discovery will enable the production of finished iodophor formulations at lower cost, reduced potential for iodine skin absorption in animals and humans, and reduced potential for iodine contamination of food and environment.

A 3-year follow-up study is underway to confirm the results of the National Oceanic and Atmospheric Administration's weather modification experiment in south Florida.[16] Preliminary results indicated that cloud seeding with silver iodide could increase rainfall by 20%.

MEERSCHAUM[17]

Crude meerschaum was not imported in 1979; however, meerschaum imported for consumption in 1978 was 14,055 pounds, compared with only 485 pounds in 1977. Somalia (78%) and the Federal Republic of Germany (22%) were the import sources in 1978. Somalia meerschaum imports totaled 11,244 pounds, and had not been imported by the United States since 1975. Customs declared value of all imported meerschaum in 1978 was $35,405, or $2.52 per pound. The crude material was used by companies in New York and Ohio for the manufacture of smokers' pipes.

QUARTZ CRYSTAL[18]

Cultured quartz crystal production in 1978 was 329,000 pounds, a decrease of 44% from that in 1977; however, in 1979, the industry rebounded, increasing production 75% to 575,000 pounds. Consumption of cultured quartz for 1978 and 1979 was 237,000 pounds and 269,000 pounds, respectively. Consumption of natural electronic/optical grade quartz crystal continued its downward trend, decreasing 57% to 24,000 pounds in 1978, and further decreasing 38% to 15,000 pounds in 1979. Production of finished crystal units during the 1978-79 period remained near the 1977 level of 74 million units. Imports of natural quartz crystal (electronic/optical grade and lasca) for 1978 and 1979 were 165,000 pounds and 427,500 pounds, respectively. Exports of natural and cultured quartz crystal were not available for the 1978-79 period.

Legislation and Government Programs.—At yearend 1979, the total Defense Materials Inventory was 2.4 million pounds of natural quartz crystal. During 1978 and through September 1979, the stockpile goal for electronic grade crystal remained at zero, making the entire quartz crystal stockpile excess material. However, in September 1979, a provisional goal of 600,000 pounds of quartz crystal was established pending possible re-evaluation of requirements. Stockpile sales of quartz for 1978 and 1979 totaled 63,000 pounds and 272,000 pounds, respectively. Currently, there is no provision for a stockpile of cultured quartz crystal.

Table 5.—Salient electronic and optical grade quartz crystal statistics

(Thousand pounds and thousand dollars unless otherwise noted)

	1975	1976	1977	1978	1979
Production:					
Mine[1]	30	513	606	317	[e]314
Cultured quartz	724	849	583	329	575
Imports of natural quartz crystal[2]:					
Quantity	585	187	265	165	428
Value	$885	$183	$394	$459	$216
Exports of electronic and optical grade quartz crystal:					
Quantity	486	645	502	NA	NA
Value	$5,713	$10,908	$4,005	NA	NA
Natural:					
Quantity	313	188	370	NA	NA
Value	$1,656	$1,626	$1,371	NA	NA
Cultured:					
Quantity	173	457	133	NA	NA
Value	$4,057	$9,282	$2,634	NA	NA
Consumption of quartz crystal	239	349	280	261	284
Natural (electronic and optical grade)	90	159	56	24	15
Cultured	149	190	224	237	269
Production of finished crystal units, number thousands	39,545	82,730	[r]73,617	74,825	73,729

[e] Estimate. [r] Revised. NA Not available.

[1] Includes lasca, and some specimen and jewelry material.

[2] Includes electronic grade, optical grade, and lasca (a feedstock for growing cultured quartz).

Domestic Production.—Three companies were reported to have produced 317,000 pounds of various grades of natural quartz in Arkansas in 1978. These companies were: The Quartz Processing Co., Hot Springs, Ark., 301,000 pounds; Ocus Stanley, Mt. Ida, Ark., 16,000 pounds; and Terry Mining Co. of Midwest, Okla., 329 pounds. The production from Terry Mining Co. was in Garland County, Ark.[19] It was reported that some of the production of The Quartz Processing Co. was used as lasca[20] in both the U.S. and overseas cultured quartz industry. During the latter part of 1978, The Quartz Processing Co. ceased production and processing of quartz material; expiration of the mining lease was the reason cited for the stoppage of operations. No future activity by the company is planned at that site.

Reported domestic production of natural quartz during 1979 occurred in the Hot Springs, Ark., area, as follows: Ocus Stanley, 14,000 pounds and Terry Mining Co., 75 pounds.[19] In addition, an estimated 300,000 pounds of lasca, used in the U.S. cultured quartz industry, was produced by Coleman Crystal Inc., Jessieville, Ark.

In 1978, eight companies, with headquarters in five States, reported production of cultured quartz for use in the quartz-cutting industry. The companies were Motorola, Inc., Chicago, Ill.; Electro Dynamics Corp., and Thermo Dynamics Corp., both in Shawnee-Mission, Kans.; Western Electric Co., Inc., North Andover, Mass.; Bliley Electric Co., Cortland, Ohio; Crystal Systems, Inc., Chardon, Ohio; Sawyer Research Products, Inc., Eastlake, Ohio; and P. R. Hoffman Co., Carlisle, Pa. In 1979, Sawyer Research purchased Crystal Systems Inc., reducing the number of growers to seven.

Consumption and Uses.—Lasca consumption reported by the eight growers in 1978 totaled 444,000 pounds, while consumption in 1979 by seven growers totaled 815,000 pounds.

Consumption of electronic/optical grade quartz crystal totaled 261,000 pounds in 1978, a 7% decrease from that in 1977. Of the 1978 total, cultured quartz increased 6% to 237,000 pounds, while natural quartz decreased 57% to 24,000 pounds. Consumption in 1979 totaled 284,000 pounds; cultured crystal consumption, 269,000 pounds, increased 14% while natural crystal continued its downward trend, decreasing 38% to 15,000 pounds. Substitution of cultured quartz for natural quartz was the reason for the large decline in the use of natural material.

In 1978, 41 companies in 16 States reported consumption of quartz crystal. Of the total, 26 consumed cultured quartz, 2 consumed natural, and 13 consumed both natural and cultured crystal. During 1979, 36 companies in 14 States reported crystal consumption with 26 consuming cultured, 1 consuming natural, and 9 consuming both natural and cultured quartz.

Fifty-nine operations in 18 States reported production of about 75 million finished crystal units in 1978. In 1979, 52 operations in 17 States reported production of approximately 74 million crystal units. Oscillators (i.e. television, CB radio, watches, clocks, etc.) accounted for 81% of the total crystal units manufactured during the 1978-79 period. Filter plates and telephone resonators accounted for 15% and 3% of production, respectively, during the period. Other uses, which included some optical units, made up the remaining 1% of crystal unit production.

Stocks.—Total reported yearend stocks of quartz crystal (cultured and natural electronic/optical grade) for 1978 totaled about 289,000 pounds. Of this total, approximately 100,000 pounds was natural quartz and 189,000 pounds was cultured quartz. By yearend 1979, natural crystal stocks had dropped to 88,000 pounds while cultured crystal increased to 218,000 pounds.

Prices.—The average reported value per pound for cultured quartz crystal for 1978 was $25.18. The average value in 1979 rose 8% to $27.16 per pound. Natural electronic/optical grade quartz had an average reported value of $16.53 per pound in 1978; value increased 45% to $23.94 per pound in 1979. Cultured quartz crystal has replaced natural quartz crystal in most applications, and the high increase in value of natural quartz in 1979 appeared to reflect the restriction of natural quartz crystal to high precision electronic and optical applications requiring high-quality natural material. The average reported value for lasca in 1978 was $0.43 per pound; this increased 28% in 1979 to $0.55 per pound. Reported average value of finished crystal units was not meaningful because of diverse end use applications and values.

Foreign Trade.—Due to a reclassification and combination of categories, export data for quartz crystal (lasca, natural electronic/optical grade, and cultured quartz) were not available for the 1978-79 period.

U.S. imports of natural quartz were designated as "Crude Brazilian Pebble;" this category included lasca, electronic grade, and optical grade quartz. The Bureau of the Census advised that imports from Mexico were not correctly classified for 1978; therefore, Mexican imports were eliminated from the statistics. Imports of natural quartz for 1978 totaled 184,000 pounds valued at $463,000. Higher grade natural quartz material imports (electronic/optical grade and lasca) were estimated to be 165,000 pounds valued at $459,000; of this, Brazil supplied 120,000 pounds valued at $63,000. The average customs value ($0.53 per pound) would indicate that most of the quartz crystal imported from Brazil was lasca. Average customs values for natural quartz material imported from Brazil ranged from $0.45 per pound to $2.47 per pound. Other import sources in 1978 were Canada, 44,000 pounds valued at $388,000; Japan, 1,000 pounds valued at $3,800; and the Federal Republic of Germany, 154 pounds valued at $3,800. The remaining lower grade quartz material, totaling 19,000 pounds and valued at $4,000, was imported from the Netherlands; however, the end use was not available.

U.S. imports of natural quartz crystal in 1979 totaled 427,500 pounds valued at $216,000; of this, Brazil supplied 364,900 pounds valued at $182,000. The average customs value, $0.50 per pound, and the range of customs values, $0.34 to $1.49 per pound, indicated that the Brazilian material was lasca. Other import sources for 1979 were Canada, 80 pounds valued at $363; Mexico, 20 pounds valued at $2,565; and Spain, 62,500 pounds valued at $30,800.

World Review.—*Brazil.*—The leading U.S. source for electronic grade, optical grade, and lasca grade quartz continued to be Brazil.

Japan.—Nihon Dempa Kogyo Co., a major Japanese crystal supplier, sold quartz crystal manufacturing equipment to Timex for use in its Singapore plant.[21]

The formation of a new expanded crystal association, The National Crystal Oscillatory Industry Association, having juridical status, was announced in 1979; membership was to be comprised of about 47 companies. One of the purposes of the group was to streamline the crystal industry which was hard hit by the large drop in CB radio business, problems in the watch crystal industry, and associated price declines.[22]

Madagascar.—Production of electronic (piezoelectric) grade quartz crystal in 1978 was 165 pounds valued at $814, or $4.93 per pound.[23] Production was located in the Fianarantsoa area and was exported primarily to Japan and France.[24]

STAUROLITE[25]

Staurolite is a naturally occurring, complex, hydrated aluminosilicate of iron having a variable but uncertain composition. Its formula can be generalized as $Fe_2Al_9Si_4O_{22}(OH)_2$. The mineral most commonly occurs as opaque reddish-brown to black crystals with specific gravity ranging from 3.74 to 3.83 and Moh's hardness between 7 and 8.

A limited rock-shop trade in cruciformtwinned staurolite crystals ("fairy crosses") exists, notably from deposits in Georgia, North Carolina, and Virginia. Staurolite in the United States was produced commercially in 1979 by E. I. du Pont de Nemours and Co. and by Titanium Enterprises, Inc. This staurolite is a byproduct of heavy-mineral concentrates recovered from a glacial age beach sand in Clay County, north-central Florida. The staurolite is removed by means of electrical and magnetic separation after the concentrates have been scrubbed and chemically washed with caustic, rinsed, and dried. The resulting fraction produced is comprised of about 77% clean, rounded, and uniformly-sized grains of staurolite, with minor proportions of tourmaline, ilmenite and other titanium minerals, kyanite, zircon, and quartz. A nominal composition of this staurolite sand is 45% Al_2O_3 (min.), 18% Fe_2O_3 (max.), 3% ZrO_2 (max.), 5% TiO_2 (max), and 5% SiO_2.

Although originally marketed only as an ingredient in some portland cement formulations, staurolite is now marketed as a specialty sand under the trade name "Biasill" for use as a molding material in iron and nonferrous foundries, owing to its low rate of thermal expansion, high rate of thermal conductivity and high melting point. It is also used as an abrasive for impact finishing metals and sandblasting buildings under the trade names "Starblast" (80 mesh) and "Biasill" (90 mesh), as well as a course grade (55 mesh).

Quantitative production data are not released for publication, but the 1978 output of staurolite decreased 14% from that of 1977; shipments increased 51% in tonnage and 15% in price per ton from 1977. Output in 1979 increased 43% compared with 1978; shipments decreased 1% in tonnage and increased 26% in value compared with 1978. Domestic productive capacity is 135,000 tons to 160,000 tons per year.

Staurolite is also produced in India in small quantities and sometimes by other nations as well.

STRONTIUM[26]

Domestic consumption of strontium on a carbonate basis was an estimated 30,000 tons in 1978, representing a 3% increase over that of 1977, and an estimated 32,000 tons in 1979, or a 7% increase over the previous year. Imports of strontium minerals were 41,289 tons in 1978 and 43,956 tons in 1979. Imports of various strontium compounds were 4,133 tons in 1978 and 5,861 tons in 1979.

Legislation and Government Programs.—Government stockpiles contained 14,408 tons of nonstockpile-grade celestite (strontium sulfate) at yearend 1978, unchanged from that of 1977. This material was available for disposal throughout 1978, but no sales were made. After 1,000 tons were sold in 1979, Government stockpiles contained 13,408 tons at yearend 1979.

Domestic Production.—Strontium minerals have not been produced commercially in the United States since 1959. However, a number of firms produced strontium compounds from imported celestite.

Table 6.—Major producers of strontium compounds, 1978-79

Company	Location	Compounds
Baker, J. T. Chemical Co	Phillipsburg, N. J	Various.
Barium and Chemicals, Inc	Steubenville, Ohio	Do.
C-E Minerals (Div. of Combustion Engineering, Inc.)	King of Prussia, Pa	Sulfate.
Chemical Products Corp	Cartersville, Ga	Carbonate.
FMC Corp	Modesto, Calif	Carbonate, nitrate.
Mallinckrodt Chemical Works	St. Louis, Mo	Various.
Milwhite Co., Inc	Houston, Tex	Sulfate.

Consumption and Uses.—Domestic consumption of strontium in the manufacture of various strontium compounds increased 3% to 30,000 tons in 1978 on a strontium carbonate basis, of which 68% was consumed as strontium carbonate, 17% as strontium nitrate, and the balance almost all as strontium sulfate or processed celestite. In terms of end use in 1978, 66% of the total was consumed in television picture tubes, 17% in pyrotechnics, 5% in ferrites, 3% in purifying electrolytic zinc, and the balance in other uses. Domestic consumption of strontium increased 7% to 32,000 tons in 1979, of which 68% was consumed as strontium carbonate, 16% as strontium nitrate, and the balance almost all as strontium sulfate or processed celestite. In terms of end use in 1979, 64% of the total was consumed in television picture tubes, 16% in pyrotechnics, 5% in ferrites, 6% in purifying electrolytic zinc, and the balance in other uses. Additional amounts were consumed directly as crude celestite in both years, usually in pigments or in purifying electrolytic zinc. Although quantitative information concerning consumption is incomplete, sales of domestically produced strontium carbonate to manufacturers of glass for color television picture tube faceplates appeared to have declined slightly in 1978 and to have rebounded in 1979. Consumption of strontium carbonate in the manufacture of ferrite ceramic permanent magnets increased in 1978, as did strontium nitrate in the manufacture of pyrotechnics and signals. In 1979, use in pyrotechnics decreased and use in ferrites increased slightly. Miscellaneous uses included greases, plastics, toothpaste, pharmaceuticals, paint, electronic components, welding fluxes, and the making of electrolytic zinc metal. Small quantities of strontium metal were produced by research companies.

Prices.—At yearend, prices quoted in the Chemical Marketing Reporter[37] were as follows: Strontium carbonate—glass grade, bags, truckloads, works, 22 to 23 cents per pound in 1978 and 28 to 28.75 cents per pound in 1979; strontium nitrate—bags, carlots, works, $24 per 100 pounds in 1978 and 1979, unchanged from 1977. Prices for strontium minerals are usually determined by direct negotiations between buyer and seller and are seldom published. The average value of imported strontium minerals at foreign ports was $45.65 per ton in 1978, up $1.10 from 1977, and $53.12 per ton in 1979, up $7.47 from 1978.

Foreign Trade.—Imports of strontium minerals totaled 41,289 tons in 1978 and 43,956 tons in 1979. All the material was imported from Mexico in 1978, and almost all of it in 1979. Imports of various strontium compounds returned to approximately the level of those for the years 1973 to 1976, increasing to 4,133 tons in 1978 and 5,861 tons in 1979. The Federal Republic of Germany was again the principal source of compounds, exporting 3,459 tons to the United States in 1978, and 3,927 tons in 1979. Quantitative data on U.S. exports of strontium compounds were not available.

Table 7.—U.S. imports for consumption of strontium minerals,[1] by country

Country	1978		1979	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Valu (thou- sands)
Canada	--	--	183	$8
Mexico	41,289	$1,885	43,406	2,304
Turkey	--	--	367	22
Total	41,289	1,885	43,956	[2]2,335

[1] Strontianite or mineral strontium carbonate and celestite or mineral strontium sulfate.

[2] Data do not add to total shown because of independent rounding.

Table 8.—U.S. imports for consumption of strontium compounds, by country

Country	1978		1979	
	Pounds	Value	Pounds	Value
Strontium carbonate, not precipitated:				
Canada	--	--	1,500	$500
Germany, Federal Republic of	39,683	$6,233	79,366	14,765
Total	39,683	6,233	80,866	15,265
Strontium carbonate, precipitated:				
Canada	12,139	6,144	14,294	7,147
China, Mainland	--	--	2,205	565
Germany, Federal Republic of	6,521,008	1,190,818	7,682,615	1,498,128
United Kingdom	5	528	1	399
Total	6,533,152	1,197,490	7,699,115	1,506,239
Strontium chromate[1]:				
Canada	623,410	591,987	420,370	435,630
France	41,667	18,824	--	--
Germany, Federal Republic of	--	--	39,683	7,485
Total	665,077	610,811	460,053	443,115

See footnotes at end of table.

Table 8.—U.S. imports for consumption of strontium compounds, by country —Continued

Country	1978		1979	
	Pounds	Value	Pounds	Value
Strontium nitrate:				
Canada	--	--	425	$391
France	--	--	220	533
Germany, Federal Republic of	158,731	$49,591	1,872	4,326
Italy	513,672	128,278	3,085,558	792,467
Total	672,403	177,869	3,088,075	797,717
Strontium compounds, n.s.p.f.:				
Canada	30,824	1,599	22,121	1,480
Germany, Federal Republic of	199,387	97,380	50,484	69,915
Hong Kong	960	475	--	--
Italy	79,366	17,631	276,899	65,419
Japan	44,383	22,295	44,489	28,544
United Kingdom	22	2,443	3	540
Total	354,942	141,823	393,996	165,898
Grand total	8,265,257	2,134,226	11,722,105	2,928,234

[1] Imported as strontium chromate pigment (TSUS 473.19).

World Review.—Deposits of strontium minerals are numerous throughout the world, but over three-quarters of known world production is usually from five major producing countries. In the 1976-79 time period, Canada dropped from the ranks of major producers and Iran rose into the ranks. Mexico, Turkey, Spain, and Algeria have continued as major producers. World production of these minerals has dropped since 1977.

Canada.—Kaiser Strontium Products, Ltd., which closed its Nova Scotia operation in 1976, auctioned off its plant equipment after unsuccessfully attempting to sell the facility in 1976-1977.[28]

Iran.—Nakhjir, a new celestite deposit located approximately 120 miles southeast of Tehran in the northwestern part of the Dasht-e-Kavir salt desert was announced. The deposit is operated by the Strontium Co., a wholly-owned subsidiary of the Simiran group of companies. Current production capacity is about 16,500 tons per year of hand-sorted celestite, the bulk of which is shipped to the U.S.S.R. and Japan. Proven reserves are 2.2 million tons of celestite, of which 518,000 tons outcrop.[29]

Turkey.—The largest producer, Barit Maden Turk, is expanding the plant capacity of its Sivas operation from 22,000 short tons per year to 44,000 tons per year by early 1980.[30]

Technology.—Manufacturers continued to look toward strontium hexaferrite derived from the carbonate as an alternative to barium ferrite magnets owing to its higher maximum energy and better temperature characteristics. Strontium-containing glazes on pottery have the advantages of nontoxicity, lower solubility, greater scratch resistance, and extended firing range without color change, over lead- and zinc-containing glazes.[31]

Table 9.—Strontium minerals: World production by country

(Short tons)

Country[1]	1976	1977	1978[p]	1979[e]
Algeria	[r]7,147	5,732	6,418	6,000
Argentina	2,264	924	990	1,000
Canada[e]	13,200	--	--	--
Iran[e] [2]	[r]6,000	11,000	16,535	9,000
Italy[e]	770	770	770	770
Mexico	24,424	50,302	36,563	36,500
Pakistan	685	402	239	220
Spain[e]	8,300	8,300	8,000	8,000
Turkey[e]	7,000	18,300	19,300	20,000
United Kingdom	5,952	5,622	[e]5,500	5,500
Total	[r]75,722	101,352	94,315	86,990

[e] Estimate. [p] Preliminary. [r] Revised.

[1] In addition to the countries listed, the Federal Republic of Germany, Poland, and the U.S.S.R. produce strontium minerals, but output is not reported quantitatively and available information is inadequate for formulation of reliable estimates of output levels.

[2] Year beginning March 21 of that stated.

WOLLASTONITE[32]

Wollastonite is a natural calcium metasilicate, usually white or light-colored, and has a theoretical composition of $CaO \cdot SiO_2$, equivalent to 48.3% lime combined with 51.7% silica. The largest single use for wollastonite has been in ceramic mixes for floor and wall tile. The mineral is also used for glazes and enamels; as a pigment and extender for paints; as a filler for plastics, rubber, and asphalt products; and in other applications.

Wollastonite output in the United States in 1978 was 15% greater in quantity and 25% higher in value than in 1977. Estimated output of wollastonite in 1979 was about 5% less in quantity and value compared with 1978. Output data are withheld to avoid disclosing company proprietary data. The two producers both years were Interpace Corp., Essex County, N.Y., and R.T. Vanderbilt Co., Inc., Lewis County, N.Y.

Wollastonite markets were discussed in a paper given at an international conference sponsored by Industrial Minerals magazine. World demand was said to have gone from 35,000 tons in 1970 to 94,000 tons in 1977. The largest probable growth area for wollastonite along with other industrial minerals was given as a functional filler in plastic systems.[33]

Interpace Corp. announced in late 1979 the sale of its wollastonite operation at Willsboro, N.Y., to Processed Minerals, Inc., a wholly-owned subsidiary of Canadian Pacific Investments, Inc. at a price of $27.5 million.[34]

Chemical Marketing Reporter, December 25, 1978, quoted the price of wollastonite, fine paint grade, bagged, in carload lots, f.o.b. works, as $86 per ton; medium paint grade, $70 per ton. The December 24, 1979, issue of the same publication quoted 400-mesh material, bagged, in carload lots, f.o.b. works, as $92 per ton; 325-mesh, $76 per ton. Through the end of 1978, the American Paint & Coatings Journal quoted prices ranging from $70 to $90 per ton for paint grade wollastonite. Corresponding prices in the December 31, 1979, issue ranged from $76 to $98 per ton.

ZEOLITES[35]

Natural zeolite production in the United States in 1978 and 1979 was probably equal to 1977's 5,000 tons. There was still no clear emergence of sustained markets. Prices were unavailable, but would not be relevant because of the market development period that zeolites were still undergoing during the period. A promising market in Europe may open up; significant sales of experimental quantities have been made.

Several domestic companies continued their applications research to develop markets for natural zeolites with very encouraging but confidential results. They are privately predicting large markets for their zeolites in the near future. The "methane from landfill" (MFL) market keeps expanding. Getty Synthetic Fuels, Inc. under an agreement with Reserve Gas Co. will provide capital and operating funds for three new MFL plants. The plants, at Monterey Park, Calif., San Fernando Valley, Calif., and near Chicago, Ill., will have a total capacity of 7 to 8 million cubic feet per day and use chabazite for the gas separation. New Jersey's Public Service Electric and Gas Co. is planning to tap the Meadowlands waste dump near East Rutherford for an estimated billion cubic feet per day of methane.

The synthetic zeolite market appears to be continually growing. An example of this growth, fluidized cracking catalysts, is examined in detail in a 1978 article.[36] The author reported that Engelhard's Mineral and Chemical Division had just completed an $8.8-million expansion of its zeolite plant at Attapulgus, Ga. This was the second such expansion in 2 years and brought the capacity up to 100 to 150 tons per day depending on product. Engelhard hopes to capture a larger share of the 130,000 tons per year American market for cracking catalysts. At a nominal $1,000 per ton that is a $130-million market. The three largest manufacturers in the zeolite catalyst cracking field are the Davison Division of W. R. Grace & Co. with a probable 55% of the market, Fitrol Corp. which has had about 28%, and Engelhard which now feels that it has 20%. The article also contains a brief description of the different processes used by each to produce their catalyst.

In the Federal Republic of Germany, Degussa and Henkel plan to up their current 30,000-metric-ton-per-year capacity to 80,000 for their HAB-30 zeolite for detergent. In France, Grand Paroisse is now making and marketing a mordenite-type zeolite.

Mobil Oil Corp. unveiled new capabilities of its ZSM-5 family of shape selective zeolite catalyst even as several plants to use the zeolites were in the planning stage. New research demonstrated that 90 to 96 octane gasoline could be made not only from methanol using these zeolites, but also from rubber latex, corn oil, castor oil, and jojoba oil. The United States and West German Governments will use the zeolite in a pilot plant to produce 100 barrels per day of gasoline from coal and the New Zealand Government is planning a 13,000-barrel-per-day plant using the Maui gas field as the methanol feed stock.

Among research reports issued during 1978 was one comparing washing efficiencies of detergents containing tripolyphosphate against those containing zeolites.[37] The conclusion was that a detergent containing 30% by weight zeolite Na and 20% sodium silicate had equivalent performance to one using 25% sodium tripolyphosphate and 10% sodium silicate. Another report indicates that Union Carbide Corp. had produced a zeolite that would selectively retain organic molecules and allow water to pass. It is reportedly the first hydrophobic zeolite. Union Carbide's Hy Siv Pressure Swing Absorption (PSA) process for hydrogen purification is being used at a Lingen, Germany refinery to produce 42 million cubic feet per day of 99.999% pure hydrogen. This is reportedly the world's largest PSA unit.

The environmental question about the possible connection of erionite with the high incidence rate of mesothelioma in two Turkish villages remains unanswered. As one scientist said, "The data are equivocal." There are simply not enough data to either rule out the connection or to confirm it.

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